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ASSESSMENT OF IMPACTS FROM INTENSIVE-USE ON ALPINE TUNDRA VEGETATION AND SOILS IN CATHEDRAL PARK, B.C. : 1984

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Summary

In 1984 parts of a feature motion picture were filmed in the near-alpine vegetation in Cathedral Lakes Park at 2225 m altitude. Trampling effects and effects from the exclusion of sunlight by temporary structures were anticipated. Therefore, to minimize trampling effects, platforms and ramps were installed. Ramps were constructed so that 20% of the incident light could reach the plants beneath.

Impacts from controlled traffic of respectively 5 walks/day (for a total of 160 walks) 25 walks/day (for a total of 875 walks) were applied to a selected area. Obtained immediately after the filming activity, the data reflect only the immediate impacts on the vegetative cover. Annual monitoring for 3 successive years and subsequent monitoring once every 3 years is recommended to determine longer-term impacts such as plant survival, invasion by weedy plants, revegetation success and erosion and reactivation of periglacial activity.

A photographic technique for monitoring impacts and inventorying vegetation was developed as a part of the study. It proved effective but further improvements are suggested.

The climate of 1984 was typical of the area, and findings should be applicable elsewhere.

A high coarse fragment content of the soil prevented significant soil compaction. It was found that under least sensitive conditions and for considerate hikers, 300 foot steps damaged vegetation but 50 footsteps did not. It is

suggested that a typical traffic intensity of 150 footstep impacts is the maximum capacity of this alpine community.

The vegetation is dominated by alpine fescue, sedge, polytrichum moss and cetraria lichens. Some difference in vegetation composition existed between the experimental plots, but this represented variants of the same vegetation community. Significant changes in the broadleaf, graminoid, and bryophyte vegetation, and bare soil components of the surface resulted from the filming activities. Severe damage was observed on the prime film set in front of the constructed cave and near the staging area. A wider fringe of moderate damage surrounded the former areas. Light damage occurred along the ramp in areas of dispersed traffic.

Growth in the dark areas beneath structures was nearly absent and plants were severely chlorotic and etiolated. Monitoring for survival and recovery is required. Growth under the ramp was greater than normal due to improved moisture availability, possibly reduced radiative cooling at night, and protection from mechanical impacts. However, the tender vegetation was sensitive to damage from freezing temperatures. Light exclusion may have severe impacts, and must be avoided. Improvements to the specifications of the ramp are suggested. Revegetation of severely damaged areas is necessary and revegetation techniques should be tested. Strict control must be exercised on the introduction of non-local plant materials. The visible presence of the study and an information presentation to film and construction personnel were significant factors in reducing adverse impacts. The construction crews were highly sensitized to the fragility of the alpine environment.

Recommendations:

- apply findings to all comparable parks.
- prevent and monitor for reactivation of soil erosion and alpine processes such as frost heaving and mud flow.
- take intensive management precautions where use intensities are projected in excess of 450 walks annually. Where less than optimum conditions prevail a lower number of walks should be considered critical.
- fire pits not be in direct contact with the underlying vegetation.
- revegetate severely damaged areas to control and/or prevent periglacial-and surface erosion, and weed establishment.
- monitor recovery of revegetated and moderately-damaged areas to detect soil erosion and weed growth in early stages allowing corrective management when the need becomes evident.
- monitor recovery for first 5 consecutive years and every multiple of 5 years after the occurrence of the impacts until full recovery is ensured (ie. Before: Yr 0; After: Yr 0, Yr 1, Yr 2, Yr 3, Yr 4, 5, Yr 10, etc.).
- use the photographic monitoring technique to monitor impact and recovery in simple-structured vegetation (examples: alpine tundra, dry grasslands, bryophyte layer of forest floor, etc.). It is cost effective, provides objective data, and minimizes field-time. Photo interpretation can be done "in-office" or by qualified contractor.
- use improved boardwalks in areas of high-intensity foot traffic. Boardwalks should be 120cm wide, of boards of 9 cm width, spaced as wide as possible (2.5 to 5cm), mounted

on stringers which are raised at least 4cm above the ground by blocks (legs placed at approximately 1m apart.

- use solid-surface platforms only where critical to prevent mechanical damage and/or severe soil compaction. Vegetation damage under such platforms can be minimized only by restoring light, temperature, and air circulation artifically.
- permit only the introduction of species recorded for each of the ecosystems of the impacted area. Effectively no plants, seeds or propagules should be brought on-site unless explicitely approved in writing by parks.

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Mr. J.W. Moore, District Manager, Parks and Outdoor Recreation Division of the Ministry of Lands, Parks and Housing, provided overall direction, coordination and liaison with the film company and ensured successful completion of the project.

Mr. W. (Bill) Eaton, project supervisor for the Parks Branch of the Ministry of Lands, Parks and Housing ensured that the experimental plots were not violated by film crews, construction crews and visitors. He made daily notes on activities and weather conditions on the site, daily measured the soil temperatures, and walked the experimental controlled traffic transects. Mr. Eaton's contribution was invaluable.

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CHAPTER 1
Introduction

CHAPTER ONE
INTRODUCTION

1.1 OBJECTIVES

In the spring of 1984 the Parks Branch of the Ministry of Lands, Parks and Housing issued a Park-Use permit to The Clan of the Cave Bear Productions Ltd. for the purposes of "shooting" a number of scenes for a feature motion picture of this name in Cathedral Lakes Park (Plate 1.1).

The script projected that at peak activity well over 100 personnel could be on-site. Furthermore it was necessary to construct:

1) a 30m fibreglass cave shell which was to serve as the background for a number of scenes.

2) a staging area to provide rest rooms, dressing rooms to make up actors, and resting and eating facilities for personnel not required on the set. This area also served as a general reception and coordination center for logistics (Access to the site was completely by helicopter).

3) a ramp boardwalk to allow personnel to move back and forth between the film set and the staging area.

As a condition of the Park-use Permit, the movie company was required to support, financially and through the provision of transportation facilities, the initiation of an environmental impact and monitoring study.

The objectives for the study were:

1) To determine effects on the environment and effectiveness of preventative management measures, which aimed to minimize the effects of trampling and compaction in areas of expected high concentrations of traffic.

2) To maintain an acute awareness among the construction workers, movie crews, and actors of the high environmental sensitivity of the film site by education, visual presence, and directives.

3) To determine the type of impacts, if any, on the environment and to advise Parks on measures to minimize impacts.

4) To obtain a better quantitative estimate of the ability of the environment to tolerate trampling.

5) To initiate monitoring and measuring of the changes and recovery of the vegetation of impacted areas.

6) To recommend methods for reclamation of damaged areas and to monitor the effectiveness of such methods.

7) To ensure that Park-use Permit Conditions, regarding the introduction and relocation of vegetation and propagules, were complied with.

It must be noted that these objectives are primarily qualitative and that no attempt was made to precisely

delineate the areas of impact. However observations regarding the extent and distribution of impacts will be presented where appropriate.

This report presents the development of impact assessment techniques, the measurements and observations taken in the spring and summer of 1984, and the conclusions reached from the analysis. A number of recommendations are presented. Data for 1985 presented in a subsequent report.

The observations and findings of the pre-filming and the immediate post-filming period, primarily reflect i) inhibition of normal growth for the 1984 growing season and ii) mechanical impacts on the standing vegetative crop. Longer-term effects such as death of plants and rootsystems, loss of growth potential from insufficient root reserves, invasion by weedy or seral species, rate of recovery/or deterioration of the vegetative cover, etc. can not be assessed until one or more growing seasons have followed the initial time of impact. In this alpine environment, which represents a particularly dynamic system of biotic and periglacial processes, ecological imbalances may result in substantial long-term damage from that which starts out as minor apparent damage.

1.2 LOCATION

The study site is located in the Okanagan Range of the Cascade Mountains (10) on the lee side of the coastal mountains immediately north of the Canada-USA border at 49° 03.63'latitude and 120° 12.24' longitude (fig 1.1).

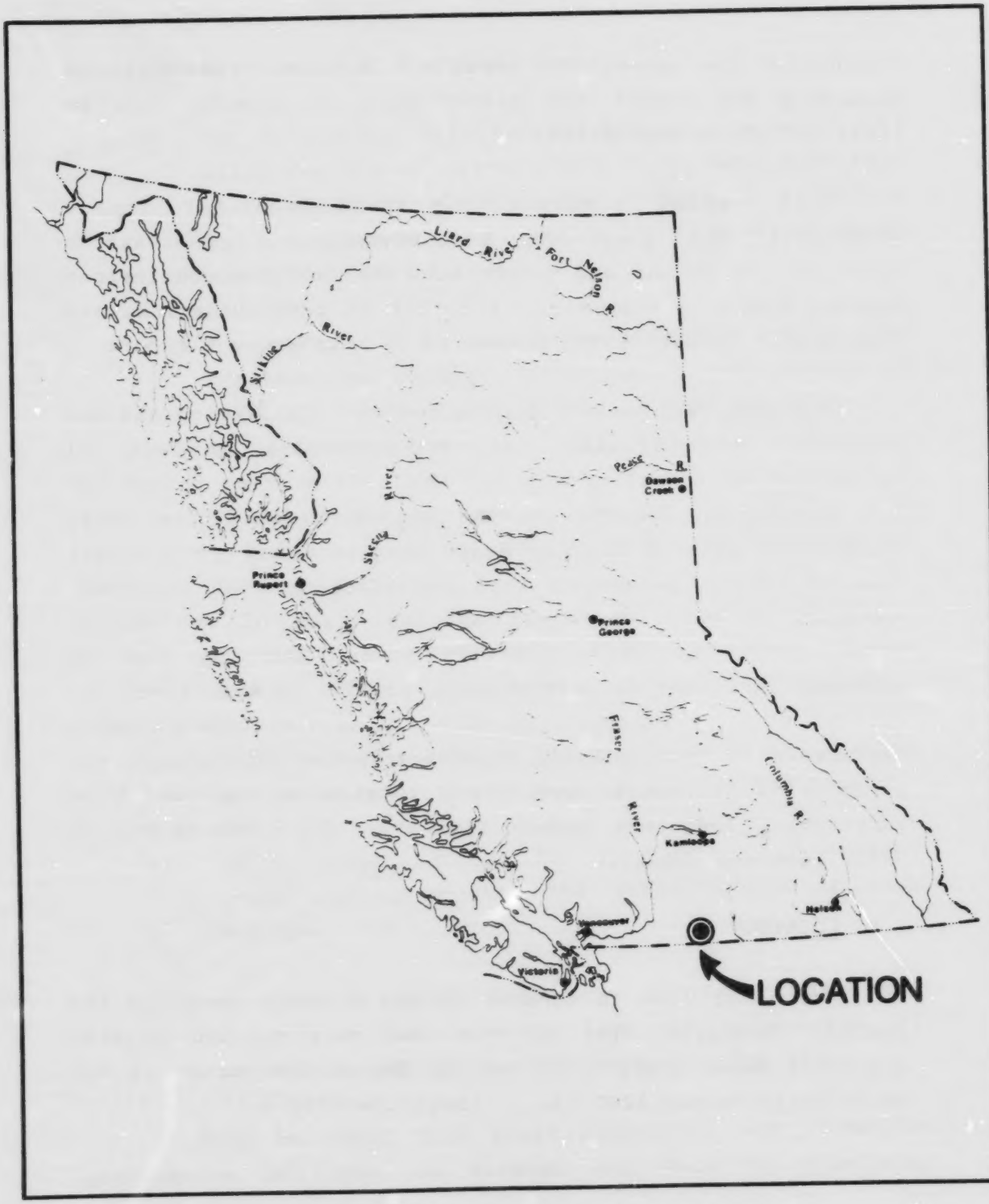


Figure 1.1 Location of Study Area

Positioned at approximately 2225 m altitude between Quiniscoe Lake and Glacier Lake at the headwaters of Lakeview Creek, the site represents a rounded, bedrock- controlled knoll projecting from the cirque headwall, Cathedral Ridge (plate 1.2).

1.3 LANDSCAPE

1.3.1 PHYSIOGRAPHY

The Okanagan Range consists of extensive, rugged alpine topography which is dissected by numerous glacially scoured, steep-sided valleys (9). The Cascade Mountains are composed of sedimentary and volcanic rocks, strongly folded and metamorphosed and intruded by granitic batholiths. The summits of the peaks, most noteably Lakeview Mountain (2518 m), Snowy Mountain (2593 m), and Haystack Mountain (2603 m), and ridges have attained an approximately uniform elevation. These peaks represent monadnocks that escaped being eroded away during the Tertiary Period. During the Pleistocene glacial period, the upper ice sheet limit has been estimated at between 2134 and 2377 m (22). As a result, areas within the Cathedral Lakes Park may have escaped glaciation. Alpine glaciation, however, was extensive and covered most of the area. Volcanic ash from eruptions at Mount Mazama and Mount St. Helens is evident in the surfical materials of the area.

1.3.2 GEOMORPHOLOGY AND GEOLOGY

The site of the Clan of the Cave Bear study area is located on a ridge (plate 1.2) between Quiniscoe and Glacier Lakes. The ridge is fairly flat-topped (plate 1.3) and

consists of shallow, colluvial materials amid numerous rock outcroppings. To the east, the area decends, and is drained by Lakeview Creek. Westward, the site is shrouded by a ridge that is some 225 m higher (plates 1.2, 1.4, B 3.1). The bedrock underlying the siste is composed of Coast Intrusions of light-coloured granodiorite, quartz diorite and gabbro (23). Overlying the Coast Intrusions on the ridge to the west is varicoloured andesite and basalt of the Princeton Group.

1.4 CLIMATE

Situated near a major physiographic boundary between the Coast Mountains and the Interior Plateau, the study area is near a region of rapid transition in climate. This has been described by Chilton (5) as follows: "The rugged Coast Mountains have a profound effect on the climate of the interior regions of the Province. Moist air masses from the Pacific move inland and are lifted as they make contact with the mountain ranges. The lifting cools the air and condenses the water vapour resulting in heavy precipitation on the windward side. As the air mass descends on the leeward side of the Coast Mountains it is much drier and it warms at a rapid rate, resulting in the familiar warm and dry climate of the southern interior."

There are no long-term climatological stations located within the Cascade Mountains. Historically, three nearby high elevation (above 1750 m) stations have been operated by the Atmospheric Environment Service. These stations are located on the Interior Plateau (Hedley Nickel Plate - 1768 m and Mt. Kobau - 1862 m) and approximately 160 km east of the study site in the Columbia Mountains (Old Glory Mountain - 2347 m). A brief summary of the climatic data for these stations is given below in **Table 1.4.1.**

Table 1.4.1 Selected Climatological Data

Station	Freeze Free Days	Degree Day >5°C	Total Precip. (mm)	% Snow	May to Sept. Precip.(mm)
Hedley N.P.	48	778	544.1	61	243.1
Mt. Kobau	62	749	585.9	66	204.5
Old Glory Mt.	21	427	755.5	73	287.0

Unfortunately, none of these stations are directly comparable with the Cathedral Lakes site. The Interior plateau sites are likely warmer and drier than the film site due to the well known rainshadow and more predominant clear skies in the region. In contrast the Old Glory site is in an area of uplifting of the predominantly westerly air masses. As a result higher precipitation and cloud cover will occur while the increase in elevation will produce lower temperatures than exist at the study site.

1.5 SOILS

The soils of the study site have developed predominantly in colluvial materials most probably weathered in-situ (Plate 1.5). There is some evidence that the site has also been glaciated as indicated by the rounded corners of the cobbles (Plate 3.15). The soils in the study area are very shallow, generally 30 to 50 cm in depth overlying bedrock. Field estimates of coarse fragments range from 60 to about 80 percent (Plates 1.5, 3.1). The development of these soils has been influenced by frost heaving (Plate 1.6), solifluction, burying and mixing of horizons, surface erosion, colluvial activity, and although not evident, by volcanic

PLATE DESCRIPTION OF
PAGES 11,12

Plate 1.1 Film-site Selection Inspected by Parks Branch staff

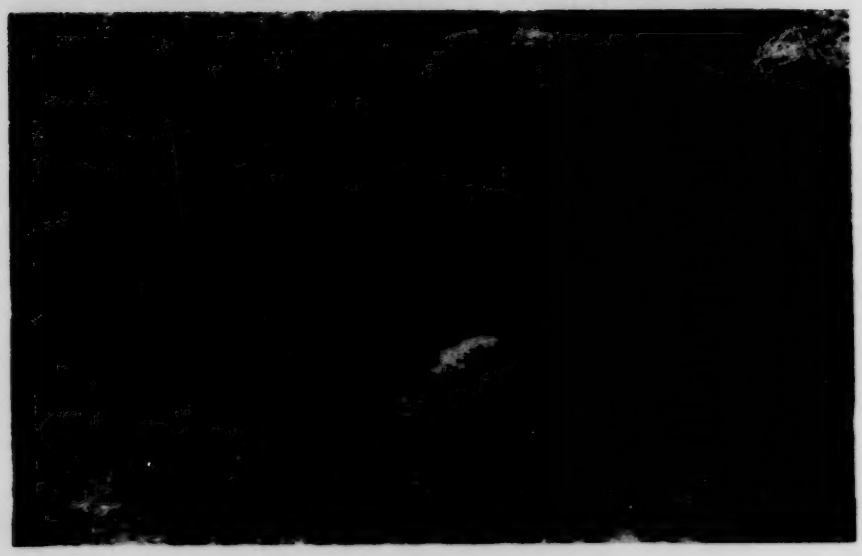
Plate 1.2 Setting of Study Area in the Landscape - June 1, 1984

Plate 1.3 Flat-topped Ridge of Shallow Soil forms the Study Area

Plate 1.4 To the East Cathedral Ridge Shrouds the Study Area

Plate 1.5 Soils have Developed in Colluvial Material Wheathered In-Situ

Plate 1.6 Continual Freeze-Thaw Cycles cause Solifluction, Frost Heaving, and Migration of Shattered Rock to the Surface



ash. As a result of the physical and mechanical weathering processes occurring in this alpine environment, rock fragments are continually being shattered from the underlying bedrock and being moved upward through the soil profile. The soils are classified as Sombric Humo-Ferric Podzols, lithic phase. The treed areas on the northerly aspects are classified as Orthic Humo-Ferric Podzols.

1.6 VEGETATION

Vegetation studies by McLean (16), Ratcliffe, Mitchell et.al. (17), and Harcombe and Kowall (11) include descriptions of the regional and local vegetation and its ecological relationships to the physical environment.

The study area is located in the Dry Interior Vegetation Region (35,29) which corresponds with the Dry and Very Dry Climatic Region of Mitchell et al. (17) of which the Very Dry Climatic Region applies to the study site. Altitudinally the area is positioned in the upper parts of the subalpine forest (Plate 1.7). However local topography, exposure to cold winds, and air flows from the adjacent higher ground of Cathedral Ridge are responsible for causing conditions approaching that of the treeless alpine environment (Plate 1.7) (In nearby less exposed areas the tree-line may be observed at altitudes in excess of 2440 m). Grazing history (22,16) and fire history (11) have likely contributed to the present appearance of the vegetation which approaches that of alpine communities. However, in all but the most exposed (sun and wind) locations the alpine communities of the study site are temporary (seral), with hardy tree species such as alpine fir, whitebark pine, Engelmann spruce, and alpine larch slowly re-invading the site. The growth of these species will be slow, and stunted growth forms may prevail.

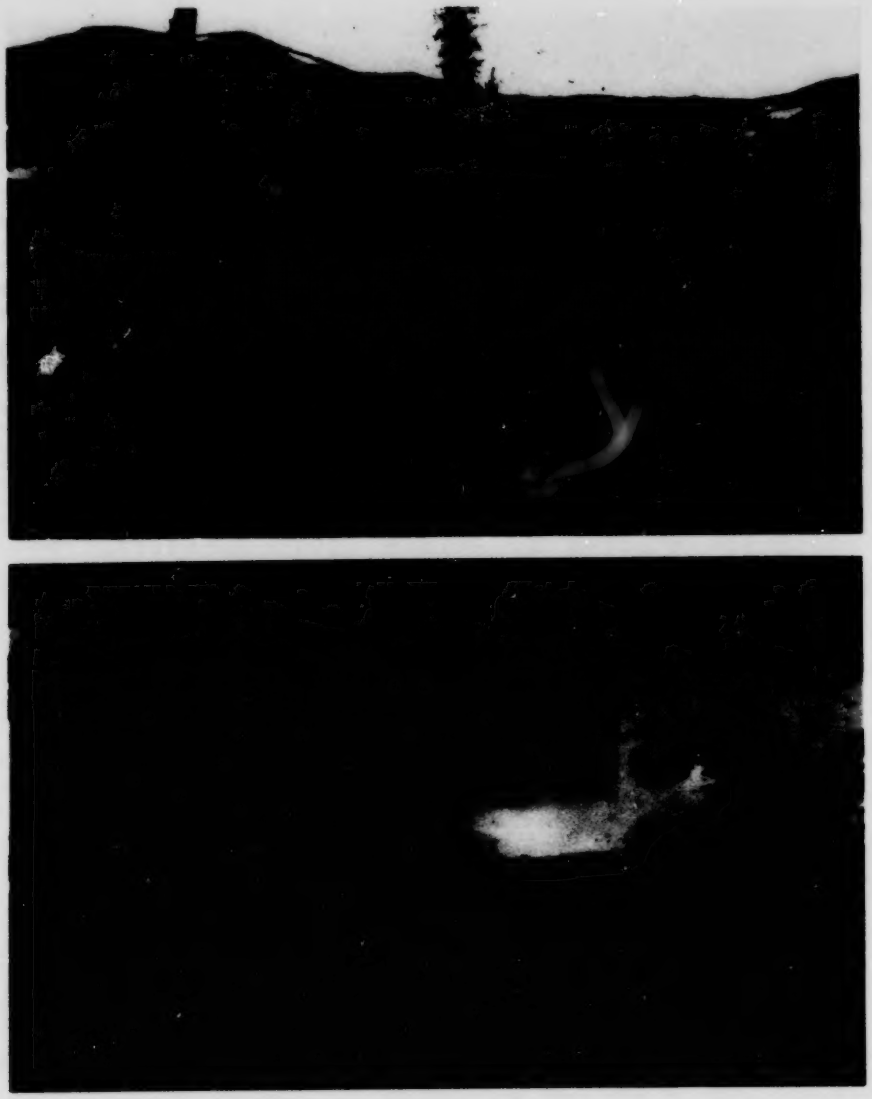


Plate 1.7 The Area is Located in the Upper Parts of the Subalpine Forest

Plate 1.8 Climatic Conditions of the Windward Side Approach those of the Tree-less Alpine Tundra

Such dynamic conditions are characteristic of the krummholz subzone which is regarded as alpine tundra zone by some (15), while others (35) regard this as subalpine. Mitchell et al. (17) regard the site as topoedaphic within the Very Dry Southern Engelmann spruce-Subalpine fir Parkland subzone (ESSF pd) characterized by alpine fir, Engelmann spruce, grouseberry and wood-rush. McLean (16) includes this area within the Alpine air-blueberry vegetation zone.

The local vegetation on the site is characterized by treeless communities dominated by alpine fescue and sedges with a cover of the mineral soil of islandic mosses (cetraria) and polytrichum moss. The well developed moss-lichen component is characteristic of somewhat moister alpine conditions while the grass-herb component resembles the communities of the alpine of the Dry Interior Region (35). Moister locations, usually in areas somewhat protected from the drying winds and sun support grouseberry, alpine pussy-toes and a variety of moisture-loving herbs including arnica and arctic lupine. Thus the local vegetation resembles the subzonal vegetation of the Very Dry Southern Alpine Tundra (ATc) which is characterized as kinnikinnick, alpine timothy and spike trisetum, and that of the Dry Southern Alpine Tundra (ATd) characterized by arctic lupine, cinquefoil (different species), and western pasque flower, which is absent here. In the treed areas of the site grouseberry, arnica, Sitka valerian and smooth woodrush reflect conditions akin to the forested and the parkland subzones of the Engelmann spruce - Subalpine fir zone, confirming the a zonal (or if preferred interzonal) character of the site. The sedges and the abundance of cetraria lichens (including Icelandic moss) and other lichens points towards a somewhat wetter vegetation. The causes for such conditions may not be simple.

Ratcliffe (22) found the vegetation of Lakeview Mountain dominated by Bellard's kobresia. She also reported a significant component of cetraria lichens in the communities. Similar vegetation was observed by the author along the Rim trail on Cathedral Ridge at altitudes over 2470 m in the Alpine tundra zone. Bellard's kobresia was found only sporadically on the study site, further confirming the topoedaphic nature of the study site.

CHAPTER 2
Methods

CHAPTER TWO
METHODS

Following the presentation and approval of a plan of operation and siting of the film props and facilities, a number of potential impacts were perceived (Table 2.3.1); the study was designed to address these perceptions.

2.1 CLIMATE

To develop an understanding of how the summer of 1984 compared with normal conditions in the Cathedral Lakes area it was necessary to re-establish the climatological station at Mt. Kobau. The station was installed June 27, 1984 and data collection continued until the station was removed September 20, 1984. In addition, data from low elevation stations in the area were available from Hedley (518 m) and Keremeos 2 (435 m).

A climatological station was not installed at the film site as it was felt that this would not improve our understanding of how the climate of the summer of 1984 differed from previous years. The soil climate (temperature) of the area was of concern since several structures and pathways were constructed in late May on the nearly frozen surface. Fourteen soil temperature probes were installed at a depth of approximately 10 cm on June 28, 1984. During the period of the project probes 2, 6, 11 and 14 were destroyed while probe 5 was moved in early June. The locations of the soil probes are given in Figure 2.1b and are listed below in Table 2.1.1. Soil temperature data were collected by Parks Branch personnel from early July until late August 1984. Graphs of the temperature data are given in Appendix A.

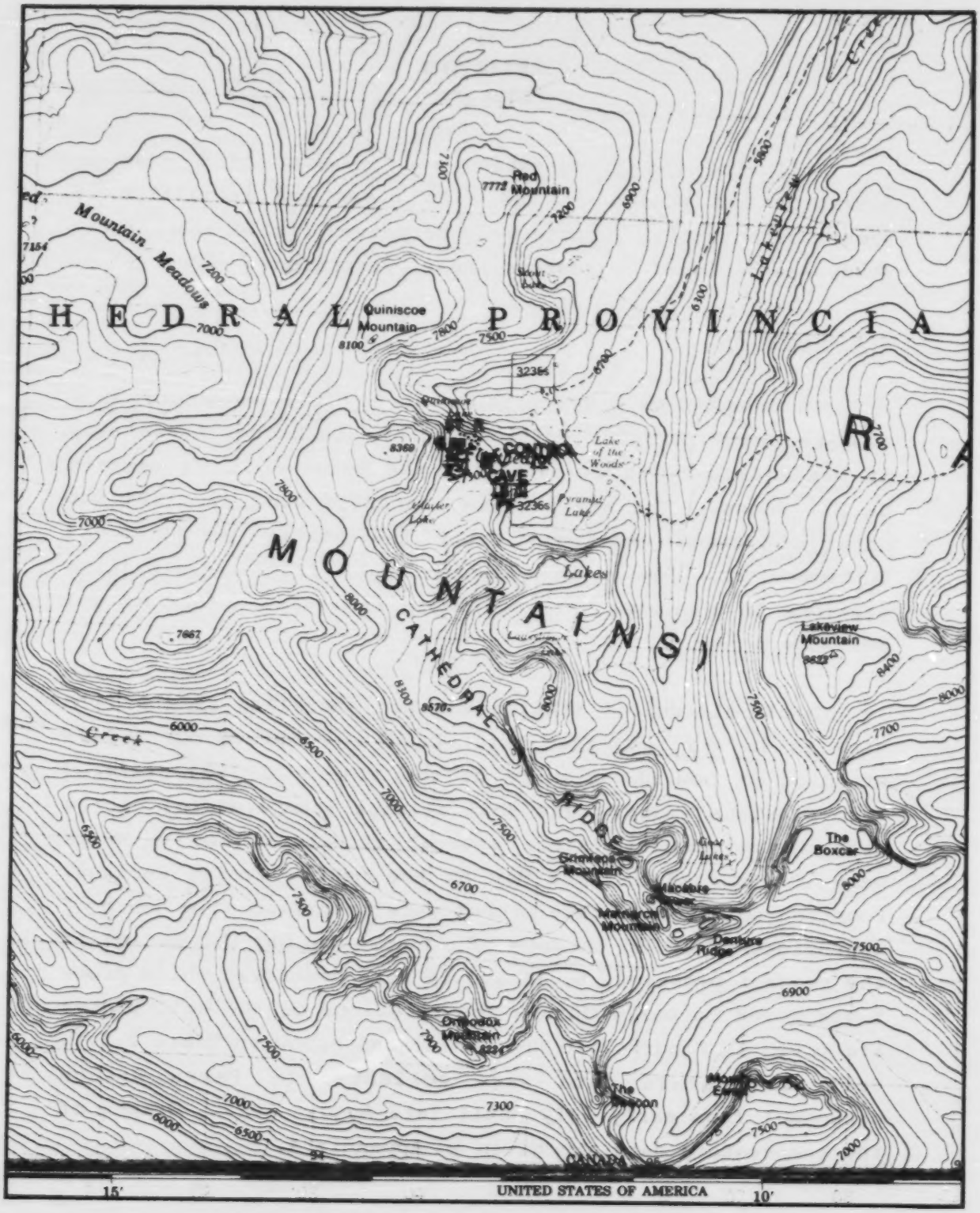


Figure 2.1a General Lay-out of Study Site

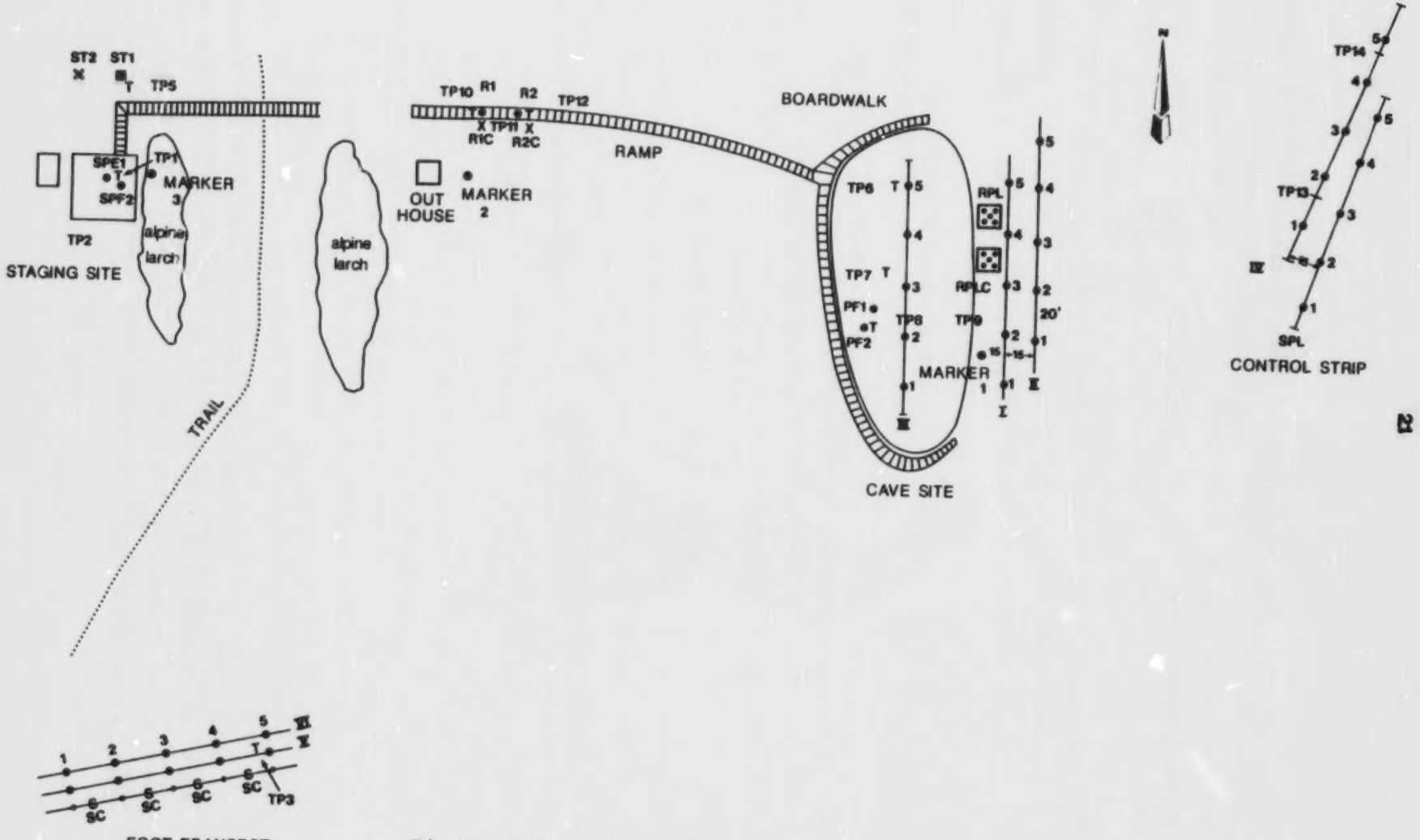


Figure 2.1b Schematic Lay-out of Study Site

Table 2.1.1

Soil Temperature Probe Locations

Probe Number (TP)	Location
1	under staging platform
2	moss covered area 10 m west of staging platform
3	grassy area of Controlled Trampling- Transect V after compaction test
4	bare area of Controlled Trampling: Soil Sampling Area
5	open area east of staging platform
6	east side of cave
7	cave centre
8	west side of cave
9	centre front of cave
10	west end of ramp site
11	south (open) of ramp site
12	east end of ramp site
13	dark moss covered soil at Control Transect IV
14	grass covered soil at control Transect IV

2.2 SOILS

On June 1, 1984 one bulk density sample was taken from each of plots 1,2,3,4 and 5 of the Soil Sampling Area Controlled Trampling test site. As well, from plot 5, a sample of the "Bf" horizon was taken to aid in the

characterization of the soils. On September 11, 1984 bulk density samples were again taken from the plots. This time, as well as taking a sample from each of the Soil Sampling Area plots, samples were also taken from the trampled transect (V). The bulk density samples were taken to determine what the trampling effects would be on the soils. Standard chemical soil analysis were determined in the Kelowna soils laboratory as well as bulk density and available water storage capacity determinations (see Appendix B 1.1 to B 1.5).

2.3 VEGETATION

Throughout the project notes were kept on activities and weather conditions on the study site (6). An Overview of Events in 1984 is presented in Table C.4.

2.3.1 LOCATING TRANSECTS AND PLOT GROUPS

Vegetation studies were designed to determine the immediate impact of the filming activities and the structures on the vegetative growth and to determine changes in the cover composition over seasons and longer periods.

a) In front of the cave (Plate 2.1) a number of scenes were to be filmed. Trampling impacts were anticipated. As these scene locations were not precisely defined at the earlier stages of construction (Table C.4) and they were subject to artistic adjustment prior to the filming, it was difficult to pinpoint where exactly the activities would take place. Therefore within the area that would be involved in the filming, two transects were located as follows (Figure 2.1b, Plate 2.2): A marker stake was located (Marker 1 in figure 2.1b) near a conspicuous

Plate 2.1 Principal Film Set in Front of Constructed Cave

Plate 2.2 Overview of Study Site Lay-out

landmark (a hollow stump in this case) located near the cave entrance. At a distance of 4.57 m from this stake a linear transect (Transect I) was located parallel to the front of the cave. A second parallel transect (Transect II) was located 9.14 m from the marker stake. On each transect a stake near the southern margin of the area of possible impact marked the starting point of the transect and was the first permanent stake of a plot. The transect stakes were driven almost completely into the ground, so that they would not inhibit foot traffic in the area (Plate 2.3). The tips of the stakes were painted pale yellow or rusty orange, which was useful for relocating them, while these colors did not disturb the natural color balances on the site. Two anchor slots on a square frame of 19.69 inches (50 cm) inside dimentions permitted accurate location of the sampling plot. (Plate 2.4). The first permanent stake of a transect served as one of the anchors for the positioning of the plot frame. The second anchor was located on the transect at the second anchor slot. Where it was not possible to drive the stake into the soil, the frame was rotated around the first stake to the nearest position that permitted placement of the stake. The first anchor for the next plot was located on or as near as possible to the transect at 6.10 m from the second anchor of the previous plot (Plate 2.5). The second anchor was again located as before. With this procedure 5 plots were located on each transect. It was speculated that this sampling density would sample at least one area representative of maximum impacts.

b) The floor inside the cave consisted of a platform raised above the ground. This area was designed for storage of supplies and equipment; and considerable traffic was

expected. The raised floor prevented impacts from trampling and compaction. The exclusion of light, solar heat, lack of ventilation and associated higher atmospheric humidity, reduced evapotranspiration, and reduced soil temperatures were hypothesized to affect seasonal development as well as longer-term plant survival. A transect (Transect III) similar and parallel to the previous ones was located at the long axis of the cave.

c) Vegetative change is to be expected even in the absence of any of the man-caused disturbances. Normal seasonal phenological development was to be evaluated. Also, if due to unusual climatic or other environmental conditions, the seasonal growth of vegetation were anomolous, such "deviations" from the average should be distinguished from "treatment effects". To observe such seasonal effects a control transect Transect IV was located at approximately 61 m SE of Marker 1. This transect was chosen to be outside the area of potential trampling impacts but as close to the cave area as possible and in a similar position in the landscape, on similar soils, and with a similar vegetative cover. Thus comparisons between the impacted transects and the control transects could be readily made. This transect was outlined with durable nylon rope, and traffic was banned from this area (Plate 2.6).

d) In the absence of a strict measurement of the amount of traffic (20) in the various parts of the set locations and staging areas, some quantification of the sensitivity of vegetation is necessary. Bell and Bliss (3) reported damage to alpine vegetation after 5 tramplings. Singer

(27) and others found that for repeated treatment of 9 to 45 walks per week the mean biomass of above-ground standing crop at the end of the season was inversely related to the number of walks per week. (20). A trampling test was designed as follows:

Three parallel, contiguous transects (Transects V, VI and Soil Sampling Area) were located on a site similar to that of the control transect (Transect IV) but well away from any film making traffic (Figure 2.1b). On Transects V and VI plots were located as previously described. The third transect served as the source for the pre-trampling soil samples for an assessment of soil bulk density (see Section 2.2) and its seasonal variability. During the season Transect V was treated with 25 walks/day, while Transect VI received 5 walks/day (Plate 3.3). A record was kept of the hiking schedule and particulars of the "hiker" (See App. C.5 and C.6).

e) A pair of plots (ST1, ST2) were selectively located underneath a platform in the staging area. The purpose of these plots was identical to that for the transect in the cave (Transect III). However, shortly after establishment of these plots the platform was relocated. The plots continued to be useful for monitoring trampling impacts adjacent to the staging platforms. A marker stake (Marker 3), located along the margin of a nearby thicket of alpine larch, aided relocation of these (and other plots).

f) Light is essential for plant survival. Even if food reserves in the root systems are sufficient to survive short periods of total darkness, considerable loss of vigor and possibly a critical loss in competitiveness will result.

Two sets of paired plots (R1, R1C; R2, R2C) were located at a measured distance and direction from Marker 2 (Figure 2.1b), so that R1 and R2 were positioned under the walking ramp (Plate 2.7), while R1C and R2C were growing in full sunlight. The plot pairs were located close to each other and were similar in all respects. The project design called for three distinct spacing widths between the boards of the ramp. However, due to miscommunications only a spacing averaging 20.4 mm, (range 19 mm - 27 mm) was constructed. This spacing represented approximately 20% of the surface. The ramp consisted of 88 mm wide boards on standard 2 x 4 dimension stringers placed directly on the ground, so that a space averaging approximately 76 mm high occurred below the boards.

g) Additional plots were located during dismantling of the structures at completion of the filming, to determine if a shock effect due to sudden exposure to the elements affected the survival of the vegetation.

Paired plots were located in the area previously covered by the cave (PF1, PF2), and the staging platforms (SPF1, SPF2). One plot of each pair of plots was covered with erosion cloth (Plate 2.4) for 3 to 5 days, while the second plot of each pair remained exposed (Note: Additional sets of plots were located in 1985 to monitor development and recovery of revegetated and damaged areas. These findings are the subject of an additional report (32)).

2.3.2 PHOTO PLOT

The photographic technique is under development (33) and was inspired by the lichen monitoring technique described

in Peterson and Douglas (19), and tested and reviewed by Kotturi et al. (12), and by Rafiq (21) and Rowe (24). This technique is the subject of a study in progress (33). A summary is presented here.

A plot is represented by the area inside a square frame of inside dimensions of 50 x 50 cm. Graduated rules (2 mm graduations) delimit the plot area. The frame has 2 slots to receive the stakes which permanently fix the plot location. On the frame is also a holder to insert a plot identification card (Plate 2.4).

A 35 mm camera (Pentax SP and later Nikon FE2) was mounted on a movie-light bracket, which in turn was mounted on a sturdy movie-camera tripod (Plate 2.8). The camera was equipped with an angle view finder, so that when the mounting table was tipped 90° and the camera was aimed downwards, one could view the object from the side.

The tripod was extended so that the view finder was at eye height (approximately 1.50 m). The tripod was then placed over the frame in such a manner that the lens aimed at approximately the centre of the plot. A flash gun mounted on the bracket provided more consistant lighting and reduced sharp shadows in bright sunshine.

A set of "grey-cards" and a label providing the date and project information were placed alongside the frame within the field of vision.

The resultant photographs were enlarged to approximately 65% of actual size (ie. 1:1.54), and color corrected using a "grey standard" (18).

PLATE DESCRIPTION OF
PAGES 31, 32

Plate 2.3 Steel Pin fixing the Location of the Plot permanently. Precise Measurement of Location allows Retrieval of the Inconspicuous Marker

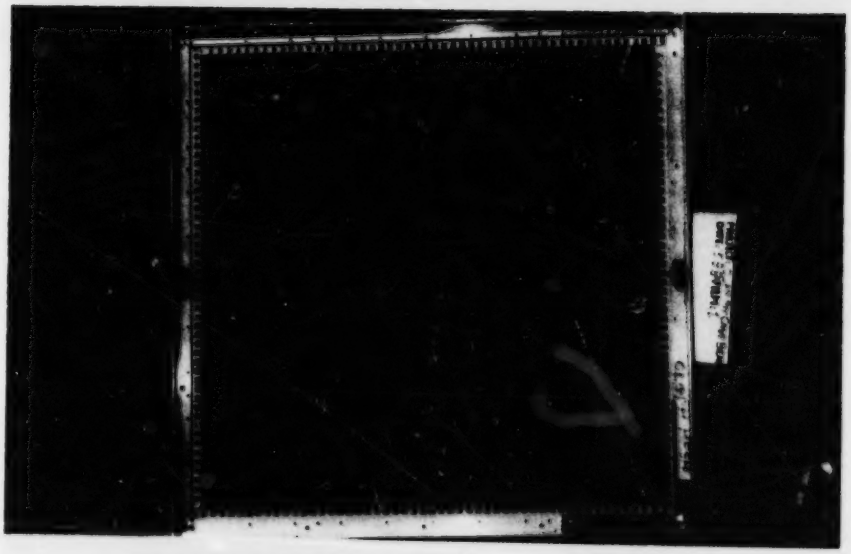
Plate 2.4 Plot Frame and Erosion Cloth for Damping Off newly Exposed Vegetation

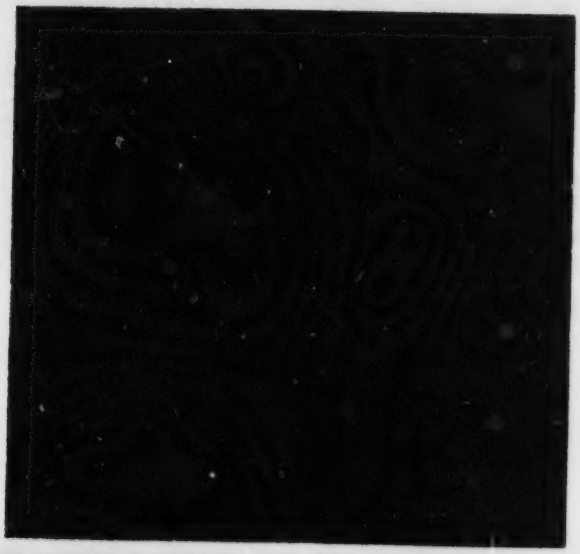
Plate 2.5 Steel Stakes, Anchoring the Plot Frames, are Driven into the Ground at 20 ft. Intervals along the Transect. In other than Uncontrolled Trampling Areas the stakes may Project well above the Ground

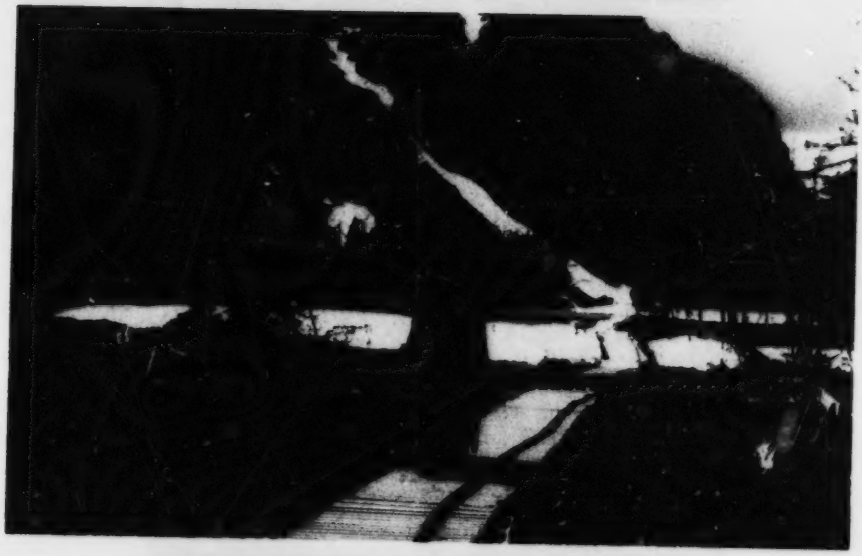
Plate 2.6 The Control Transect Served to Measure Seasonal Changes in Vegetative Cover. The Transect was Clearly Marked with Nylon String, and Foot Traffic was Banned from the Area

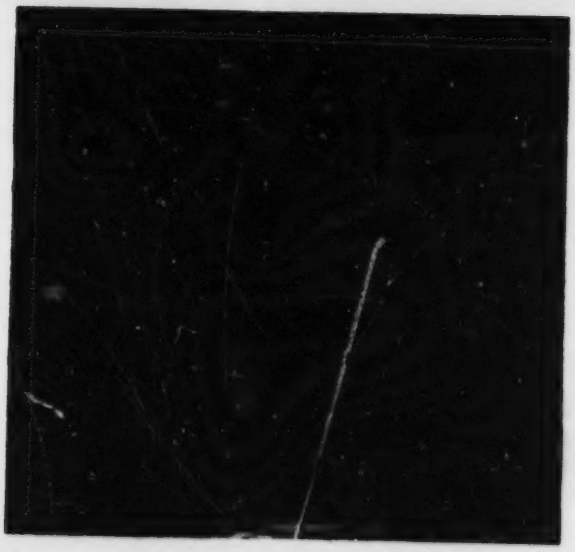
Plate 2.7 Ramp, connecting Cave Set with Stageing Area Monitoring Plots (R) are Located in the Foreground Under and to the Left of the Ramp

Plate 2.8 A 35 mm Camera mounted on a Movie-light Bracket was mounted on a Sturdy Tripod and Positioned approximately over the Centre of the Plot Frame









2.3.3 DATA

On the enlarged photographs gridlines were drawn between corresponding graduations on the rules between 5 cm and 45 cm. In one arbitrarily selected direction 41 lines were drawn at every 1 cm graduation, while in the alternate direction every odd numbered graduation provided 21 lines for a total of 861 gridpoints at the line intersections. (Note Micro Uniball pens, Faber-Castell gave satisfactory results).

In the field the presence/absence of species in each plot and comments on abundance were noted (App. C.1.2) and representative samples of each species were obtained from elsewhere in the study area. These notes and the samples were essential reference aides in the interpretation of the photographs.

The vegetation in the plots was categorized into the following cover types (Bracketed notation represents computer code for the type)

Broadleaved shrub
Broadleaved herb (VEG 3)
Graminoid herb (VEG 5)
Total herb (VEG 7).
Bryophytes (including Selaginella) on soil (VEG 9)
Unknown (VEG 14)
Litter (VEG 6)
Total Rock, Boulders, and Stones (VEG 10)
Unvegetated Rock, Boulders, and Stones (VEG 11)
Damaged and Unvegetated Soil Surface (VEG 12)

Due to inconsistancies in the interpretation of these categories by two interpreters (B and T under Interp, App. C

Table C.2) additional categories were recognized and the above categories were estimated through calculations. The additional categories are:

Broadleaved tree (VEG 1)
Coniferous tree (VEG 2)
Living graminoid herb (VEG 4)
Total Bryophyte (soil, rock) (VEG 8)
Total non-vegetated surface area (VEG 13)

Each gridpoint was tallied into one of these categories depending on the dominant (exposed surface) cover at that point. Upon completion of all gridpoints, the tally for each category was counted and a % crown cover calculated. The data were entered into a computer file for further processing (App. C Table C.2).

2.3.4 CALCULATIONS AND ANALYSES

2.3.4.1 Cover Value Estimation

Due to inconsistancies in the interpretation of the cover-type categories between photo-interpreters (B and T under Interp, Appendix C, Table C.2) it was necessary to estimate some categories as follows (see Appendix C, Table C.7 Lines 6 to 17):

For interpreter "T" the total graminoid cover was estimated to be the sum of Living Graminoid Herb (VEG 4) and Litter (VEG 6). Since broadleaved herbs generally were a minor component of the vegetation cover, and its dead foliage tended to disintegrate rapidly, the error in this estimate appeared acceptable.

For interpreter "B" dead and living graminoid matter were included, leaving only unrecognizable foreign detritus (chainsaw wood chips) in the litter category.

In the case of interpreter "T", Total Bryophyte (VEG 8) included the rock and boulder surfaces occupied by epilithic lichens. The component of Bryophytes on the Soil Substrate (VEG 9) was estimated by subtracting the rock surface (Boulders and Stones (VEG 10) from Total Bryophyte (VEG 8)). This is a reasonable estimate since most rock was completely covered with crustose lichens. An underestimation may have resulted from partially covered rock surfaces.

Where calculations resulted in negative estimates, the cover values were set to 0%, as such estimates reflected estimation errors rather than data.

The results are tabulated in Table C.2 of Appendix C.

2.3.4.2 Analysis of Variance of Pre-Treatment Transect Vegetation

To determine if significant differences existed among the sampling transects with regard to the percent cover of each of the cover types, a Single Classification Anova (28) procedure for balanced data was used. This SAS procedure (25,26) was applied for the vegetation cover types: Broadleaved Herb (VEG 3), Graminoid Herb (VEG 5), Bryophytes on Soil (VEG 9), Unvegetated Rock, Boulders and Stones (VEG 11), and Damaged and Unvegetated Soil Surface (VEG 12) (See Appendix C, Tables C.2 and C.7).

2.3.4.3 Analysis of Variance of Treatment Effects on Transect Vegetation

The data of the plots of each transect were stratified into Before (B), After (A), and Damaged (D) (See App C Tables C.2 and C.3 under TIME). "Before" refers to data collected before the occurrence of impacts (See Table 2.3.1 for specific impacts). The data from after the filming were divided into After (A): displaying no visible symptoms of trampling impacts, and Damaged (D): exhibiting visible evidence of trampling impacts. The distinction of the categories was desirable and necessary since there is no need to demonstrate the obvious and the sets of data are clearly distinct in terms of means and variability.

This data (See App C Table C.2) was analyzed in a similar manner as the data in 2.3.4.2 using a Two-Way Analysis of Variance (28) for unbalanced data, using the SAS (25,26) procedures.

Table 2.3.1
Summary of Environmental Effects Under Study

Feature	Effect and Duration	
Cave	Partial shading while under construction/removal	4 weeks
	Total darkness while complete	8 weeks
Ramp	Partial shading and shelter	9 weeks
Staging Platform	Central 7X7m completed only latteral light	7 weeks
	Expansion to 15X14m	5 weeks
	Central under construction	1 1/2 weeks
Generator Platform	Intense shading, close to the ground or directly on the ground	5 1/2 weeks
Construction Period	Moderate traffic (approx 15-20 persons)	12 weeks
Film Shooting Period	Intensive traffic (well over 100 persons on site at peak time)	4 1/2 weeks

CHAPTER 3
Results & Discussion

CHAPTER THREE
RESULTS AND DISCUSSION

3.1 CLIMATE

The climate of the study area was mapped in 1974 at a scale of 1: 125 000. The Climatic Capability for Agriculture of the Cathedral Lakes area was classified as 7GF, indicating a freeze free period of less than 30 days and degree day accumulation > 5 degrees C less than 670. The 1984 data for climate stations in the vicinity of the study site are presented below in Table 3.1.1.

Table 3.1.1a Mean Daily Temperature (degrees C)

	JUNE		JULY		AUGUST		SEPTEMBER	
Station	84	AVG	84	AVG	84	AVG	84	AVG
Hedley	15.8	16.7	20.7	19.9	19.7	19.0	12.7	14.6
Keremeos	16.7	18.2	21.7	21.6	20.7	20.9	13.8	16.4
Mt Kobau	-	8.2	12.2	12.2	11.9	12.1	7.1	7.8

Table 3.1.1b Precipitation Comparison (mm)

	JUNE		JULY		AUGUST		SEPTEMBER	
Station	84	AVG	84	AVG	84	AVG	84	AVG
Hedley	60.0	34.8	5.0	26.7	80.7	31.7	13.4	19.5
Keremeos	31.4	27.1	2.2	20.3	26.0	22.2	12.8	12.8
Mt Kobau	-	41.6	-	31.9	-	40.5	-	26.6

These data indicate that the mean daily temperatures were near or slightly below normal during the summer of 1984, however; precipitation during July was well below normal at

Hedley and Keremeos. A more detailed breakdown of the 1984 precipitation at all three sites is presented in Table 3.1.2.

Table 3.1.2 Detailed 1984 Precipitation (mm)

Station	June 27/July 26	July 27/Aug 21	Aug 22/Sept 20
Hedley	9.0	78.5	10.6
Keremeos	3.6	23.2	8.0
Mt Kobau	16.6	7.0	16.4

These data demonstrate the effect of convective storms in the interior of the Province. For example, of the 78.5 mm of rainfall received at Hedley (July 27 to August 21) more than 57 mm was deposited by 2 thunderstorms. One of these intense storms deposited only 10.2 mm at Keremeos (August 12) while the second, depositing 30.8 mm at Hedley, released only 3.0 mm at Keremeos. The phenomena of uneven precipitation patterns in the interior due to convective storms is well known and the 1984 data further verifies this event. In addition, Mt. Kobau, in 15 years of record, has had total August precipitation ranging from 1.5 mm in 1967 to 125.5 mm in 1976, while something near the average of 40.5 mm ± 40% has been observed on only 3 occasions. The low precipitation observed in 1984 at Mt. Kobau and the surrounding area was likely less than average, but such extremes are common throughout the interior of the province. Marsh (personal communications) has observed that the climatic moisture balance for the period April to September 1984 was extremely moist throughout the interior of British Columbia. This was especially true of the period April to June; however, at Cathedral Lakes the soil was frozen until mid June and often

dare of any snow cover. Consequently, any moisture received at the surface during this period was likely not available for plant growth.

In contrast, the temperature data at Mt. Kobau are remarkably near the values of the long-term normals during July and August and the partial month of September. In addition, the 1984 freeze free period was 58 days (Average freeze free period = 62 days) while the degree day total >5 degrees C was 223 for July and 215 for August compared with normal values of 224 and 222 respectively. Further analysis of the data for Mt. Kobau during its period of operation from 1966 to 1980 is presented in Table 3.1.3 below. These data indicate that frost and snowfall can be observed in any month, with frost in August anticipated 1 year in 2 while snow may be observed in August 1 year in 5. It is anticipated that the Cathedral Lakes area would have a somewhat harsher climate.

Table 3.1.3 Selected Data for Mt. Kobau

Data Type	May	June	July	August	Sept	Oct
Risk of Frost %	100	100	53	47	93	100
Risk of Snow %	100	73	27	20	54	100
Normal Snow cm	34.2	3.7	0.6	0.6	5.0	25.6

The on-site soil temperature data are shown in Figures A.1 to A.14 in Appendix A. Probes 1,6,7,8 and 9 were all under solid man-made objects. In all cases these probes showed only minor changes in day-to-day temperature and virtually no change between morning and afternoon observations while the structure was in place. The areas with these five probes were exposed to the air but little or

no direct sunlight until the structures were removed in mid-August. The tents were removed from the platform above probe 1 by August 7 and the soil temperature began to rise. The platform was completely removed by August 15 and the soil temperatures increased further. The 4 probes beneath the cave showed an even more stable climate prior to removal of the structure. Diurnal variations were nearly non-existant prior to August 7.

After the cave and tent platform were removed, the soil temperatures rapidly resumed values near the level of the soil temperature probes in more open locations.

The remaining probes may be grouped into 2 categories: those in the open (probes 2,3,4,5,11,13 and 14) and those under semi-open structures (probes 10 and 12).

The probes in the open show consistent temperatures during the morning observations, while the afternoon temperatures vary from a high at probe 13 to a low at probe 14. These large discrepancies in afternoon temperatures are likely due to variations in the surface albedo (reflectivity). For example, probe 13 was located below a dark (nearly black) moss covered site, while probe 14 was located below a well insulated grassy covered surface. Probes 10 and 12 were located beneath a semi-open walkway and the temperatures recorded were warmer than those observed under covered sites but cooler than those sites that were not covered by a man-made structure.

No winter data were collected on site in 1984 but examination of the long-term data at Mt. Kobau indicate that minimum temperatures between -20 and -30 degrees C occur

annually. The extreme minimum of -38.9 degrees C was recorded in December 1969. It is likely that the Cathedral Lakes site is even more inhospitable with lower temperatures and persistent strong wind from the west.

In conclusion, the summer of 1984 seems to have been typical with near normal temperatures and the erratic precipitation patterns common to the region. Soil temperatures decreased as the cover from man-made objects increased. Below the cave, soil temperatures were nearly isothermal, while in the open, diurnal variations in excess of 10 degrees C were observed (July 27, 1984). This is likely a direct response to the lack of incoming solar radiation and corresponding surface heating below the various man-made structures.

3.2 SOILS

Horizonation of these soils is typical of that found in alpine environments. The surface horizon is enriched with organic matter obtained by the decay of plant roots and incorporation of decomposing surface vegetation. Because of the organic matter influence, this soil layer, which is characteristically called an "Ah" horizon, has a dark brown or black colour (see Plate 1.5). The next lower horizon is one which is enriched with amorphous material, principally iron and aluminum combined with organic matter. This layer, which is called a "Bf" horizon, usually has a bright, reddish-brown colour.

From the laboratory results of the one "Bf" horizon sampled, the soil is classified as a Sombric Humo-Ferric Podzol. As these soils are typically shallow overlying bedrock, they are also distinguished as being a lithic phase.

These soils from the study area are similar to the Pitin soils described by Green and Lord (8) for the 92 H/SE soils map sheet and Kowall (14) for the 82E soils map area (Appendix B.3.1). The texture of the fine fraction less than 2 mm of the Bf horizon was determined to be a sandy loam having 46 percent sand, 47 percent silt, and 7 percent clay (see soil triangle, Appendix B.2, Fig. A.2.1). With a minor change in either the sand or clay content the soil texture could easily change to silt loam or loam. Organic matter content is highest in the surface "Ah" horizon and decreases with depth. Total nitrogen, exchangeable cations, and cation exchange capacity appears to be correlated with the organic matter content and decreases with depth. Available phosphorus also decreases with depth (see Appendix B.11).

Being on a ridge, the soil moisture status of the study area is poor. Any available soil water derived from rainfall or snowmelt is drained away from this moisture shedding site. The shallowness of the soil and its high component of coarse fragments (approximately 70 percent) greatly reduces its capacity to retain water (Plate 3.1). The ridge is generally windswept, decreasing snowdepths during the winter months and increasing evapotranspiration during the growing season. Soil moisture conditions are better on the north slope where snow accumulation is greater and snowmelt is slower (Plate 3.2), although this affects plant growth by decreasing the length of growing season. The available water storage capacity of the surface "Ah" soil layer is variable ranging from about 13 to 18 cm of water per 100 cm of soil.

The bulk density of the surface "Ah" soil layer varied from 0.78 to 1.08 gm/cm^3 in the control (transect) sampled in June. The bulk densities were determined in the laboratory by the cloud method. The bulk densities that were measured

in September by the volume displacement method are also variable. The bulk densities on the control plot varied from 0.60 to 1.58 gm/cm^3 and those on the trampled plot varied from 0.46 to 0.97 gm/cm^3. The variability in the bulk densities was probably due to the amounts of fine gravel in the samples. This would explain why the September control transect sample had higher bulk densities than the September trampled transects. An increase in bulk density would have indicated that the trampling had caused some soil compaction. Generally though, trampling most likely did not significantly affect the bulk densities of these soils because of their high content (60 to 80 percent) of angular, coarse fragments. Freeze/thaw cycles would also lessen compaction in relatively short order. Soils with lower amounts of coarse fragments are affected by trampling, having the resultant effect of higher bulk densities and, therefore, increased soil compaction (11).

Generally, in their natural vegetative state, these soils are subjected to a minimal amount of erosion, although the periglacial processes are active and any exposed soil is subject to wind action. Areas that have been trampled and the vegetative cover lost are subject to more soil erosion, especially once the plant roots have died and rotted. Under these conditions, active erosion can occur from running water from snowmelt or rain storms especially from raindrop action. Soil erosion would not be too prevalent on the flatter top of the ridge but as the slopes increase so would the probability of erosion. Although the sampling for bulk densities may not have been carried out in a rigorous scientific manner, the results indicate that significantly increased soil compaction did not occur and no real harm had occurred to the soil. This was probably due to the high coarse fragment content of the soil buffering the impact of trampling. The effect of

trampling on the vegetation was more far reaching. With the death of the vegetation, the soil was subject to increased erosion. Also, eventually there would be a decrease in the organic matter content of the soil, adversely affecting the soil moisture status as well as the soil fertility. These factors could impact on the revegetative capacity of these soils.

3.3 VEGETATION

3.3.1 GENERAL

The species composition of each plot is presented in tables C.1.2 of Appendix C. Photographs of the plots "Before" and "After" impact are presented in Appendix C.8, Plates C.8.1 to C.8.40

The photo interpretation data for the Vegetation Transects is summarized in Table C.2. The data for observations (OBS) 6 and 5 and observations 11 to 19 and the remainder reflect the difference in the concept of Litter (VEG 6) between interpreters "B" and "T".

In Unvegetated Rock, Boulders and Stones (VEG 11) 0% cover associated with Interpreter "T" reflects the estimation assumption that all rock surfaces were covered with lichen. Where this assumption is in error the cover of Bryophytes on Soil (VEG 9) may be underestimated. Damaged and Unvegetated Soil Surface "(VEG 12)" reflects a significant difference between impacted and non-impacted plots.

At this stage of the project not all impacts can be identified or considered final. The mechanical injury and removal of biomass can be determined. However plant survival and effects on growth will become evident in subsequent years. Also recovery rates of the vegetation, and "weed invasion" will become evident over a number of years. This report therefore focuses on the mechanical impacts of trampling on standing biomass, the health or vigor of plant species following treatment, and the growth, or lack thereof, of the impacted species.

Factors influencing plant performance at various parts of the study (Table 2.3.1) include mechanical damage, light intensity, soil compaction, soil temperature, soil moisture, plant hardiness, air temperature, and humidity. The variation and changes in these factors in the course of the study are described in the appropriate sections of this report. In this section the effects of these factors on plant growth will be included where appropriate.

3.3.2 COMPARISON OF TRANSECTS

To determine if differences existed between the various transects single classification analysis of variance procedure (PROC ANOVA; 26) was applied to the pre-filming (TIME=B) data for each cover category (Table 3.3.1). Differences between the mean cover values for each transect were tested for significance with Least Significant Difference (LSD) and Duncan Multiple Range tests.

The transects did not differ significantly with regard to the coverage of broadleaved herbs. Mean coverage values ranged from 14.6% for Transect VI to 26% for Transect III. This difference between means was significant (α=0.05) for LSD, but not for Duncan's test. As this vegetation component is an important component of the total cover, the lack of overall significance is to be noted.

The total cover of graminoid plants, grasses and sedges, varies significantly (α=0.05) between the transects. The mean coverage of this dominant vegetation element ranges from 47.2% for Transect III to 72.4% for Transect V. The former (III) is richer in low broadleaved species which, due to a lesser grass cover, are visible.

The variation between transects for bryophytes is highly significant. Mean exposures of lichens and mosses (including selaginella) ranges from 16% in Transect II to 0.2% in Transect V. A lower cover of grasses and broadleaved herbs may account for some of the exposures of lichens and mosses. However, it appears that greater stoniness and presence of boulders (Plates 3.1, C.8.1...C.8.10 of Appendix C.8) coincides with an increased richness in lichens and mosses, and a reduction in the abundance of grasses and broadleaved plants. In view of the active periglacial processes nearby, it may be speculated that this area has become inactive more recently than other areas. The lichen cover would then reflect an earlier stage of primary succession. Alternatively, previous grazing by sheep and horses (22, 7) may have removed an earlier vegetative cover and the present cover reflects an earlier successional stage. Reactivation of periglacial processes following removal of the vegetative cover would support the first speculation. "Frost-boils" of stones were noted at the time of initial data collection.

Even though the visible coverage of stones (<5cm) and boulders (>5cm) is limited, a significant variation exists. Transect II has the greater exposure of rocks (5.4%). Transect I, although not significantly differing from the remaining transects, follows closely with a mean exposure of 4%. The remaining transects range from 0.2 to 1.0% mean exposure of rock. Stoniness was discussed in the preceeding paragraph (Plate 3.1).

The highly significant variation in the unvegetated component appears to be due to the discussed difference in concept between interpreters. Transect II was interpreted by Interpreter "B" while nearly all of the remaining transects

Table 3.3.1
Analysis of Variance[1] of Pre-Treatment Transect Vegetation (Sites)

	Broadleaf Herbs	Total Graminoid Herbs	Bryophytes	Exposed Rock	Unvegetated Soil
Anova % Sign. Lvl	82.3	97.4	99.9	99.5	99.9
Sign Differing Transects (α =.05)					
LSD (% Cover)	10.44	14.89	7.31	2.85	1.69
Gp A	III	V,(I,VI)[2]	II	II	I
vs					
Gp B	VI	II	IV,III,VI,V,I	VI,I,IV,V,III	V
vs					
Gp C		III			II
Duncan					
Gp A	none	V,I,VI	II	II	I,III,VI,IV,V
VS					
Gp B		III	IV,III,VI,V,I	VI,I,IV,V,III	II
Transect Mean % Cover (N=5)					
I	16.0	67.0	2.0	4.0	5.0
II	19.6	56.8	16.0	5.4	0.0
III	26.0	47.2	2.8	0.2	4.0
IV	23.8	59.2	5.6	0.2	3.4
V	16.2	72.4	0.2	0.2	3.2
VI	14.6	66.4	0.4	1.0	4.0

[1] OS SAS 82.4

—— $\alpha \geq .05$; ═══ α .01; ═══ α .001

[2] Difference significant for one of the alternate groups,but not all

were interpreted by Interpreter "T". As this component of the total coverage is minor, this estimation error does not appear to be important.

Although differences exist between the transects, these differences are mostly in the cover components of species of low abundance. Throughout the transects grasses and sedges form the dominant vegetation with broadleaved species associated in limited abundance (Table C.1.2). Bryophytes and rocks (stones and boulders) represent a minor component of the vegetative cover. Transect II displays the greater variation on this basic pattern, and it might be considered a "stony- phase variant". The basic community is dominated by alpine fescue with California oatgrass or sedges (primarily northern single-spiked sedge) codominating and a significant proportion of lichens (cetraria species), mosses (polytrichum mosses) and the moss-like selaginella forming a bryophyte layer. Blueleaved cinquefoil is evenly distributed throughout the community while spike-like goldenrod occurs in patches. The difference between the transects represent variations of the single basic community type. They do not appear indicative of major differences in ecological conditions.

Elsewhere in the study area distinct community types are found in response to differences in moisture regimes due to late melting of accumulations of drifted snow.

3.3.3 SEASONAL GROWTH

As vegetation develops through the season changes in cover occur. Such changes may be substantial for deciduous

species, while species with permanent standing biomass such as bunchgrasses and evergreens would undergo little change. In the case of bunchgrasses with large amounts of foliage from previous years, living foliage may be hidden by the straw. Lichen and bryophyte growth tends to be very slow and removal of the overstory of grasses and herbs may create an apparent increase in cover of these species.

Transect IV (control) (Plates 2.6, C.8.16 to C.8.21) displayed the normal seasonal development. Changes in canopy coverage from before filming to after filming are presented in Table 3.3.2. Due to the presence of a somewhat higher proportion of shrubby cinquefoil on several plots (Table C.1.2) the broadleaf category (shrub and herb) may be somewhat higher in cover than in some other transects. Little change in broadleaf cover occurred, as much of the foliage had developed by late June, when the first photographs were taken. The crest-position of this site may have led to less snowcover and higher insolation, thus promoting earlier development of the vegetation. Little change in the gramnoid plant cover occurred, although some increasing trend may be evident. The contrast in the bryophyte component of plots 1 and 2 versus plots 3, 4 and 5 appears to reflect the variability of the vegetation of the transect.

3.3.4 EFFECTS OF TRAMPLING

Trampling effects were determined on Transects I, II, V, VI and on paired plots ST1 and ST2 (Table C.2) and on R1C and R2C. The latter four plots were not originally intended for this purpose. Plots ST1 and ST2 were originally located underneath a platform. However, within a week these platforms were relocated and the area was subjected to foot

Table 3.3.2 Treatment Effects on Canopy Cover of Vegetation Categories for Each Plot per Transect (Site) for 1984 (Change in % Canopy Coverage)

Transect	I					II					III					IV					V					VI					ST		R				
Plot No	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	1	2	IC	2C	MEAN	SD*
Visual Damage	L	L	H	H	M	-	L	L	H	M	-	L	M	L	H	-	-	-	-	-	M	M	L	L	L	-	-	-	L	-	-	-	-	-	L	L		
Vegetation Category																																						
Broadl. herbs (Veg 3)	0	-15	-10	9	-1	3	2	2	-12	-5	-18	-9	-27	-3	-14	-6	4	-1	-6	-10	-6	-14	-2	-8	-4	-2	-5	-5	2	-4	-16	-2	17	13	-4	-2	-4.417	8.530
Total Gramin. herbs (Veg 5)	1	15	-49	-3	5**	-2	-4	-3	-35	-9	-17	16**	26	15	28	2	-5	1	8	12	8	18	-3	8	5	4	1	6	0	4	-12	-3	-4	4	-3	0	0.972	14.322
Total herbs (Veg 7)	1	0	-59	6	4	1	-2	-1	-47	-14	-35	7	-1	12	14	-4	-1	0	2	2	2	4	-5	0	1	2	-4	1	2	0	-28	-5	13	17	-7	-2	-3.444	15.628
Bryoph. on Soil (Veg 9)	1	-2	5	0	-1	-1	-2	-4	-25	-25	38	-3	-8	2	-1	5	2	2	0	0	0	0	0	-1	0	-2	0	0	0	0	0	-5	-8	-18	0	0	-1.417	9.566
Rock (Veg 11)	0	0	6	11	2	-2	7	-1	18	5	0	1	1	0	0	0	0	0	0	0	2	2	6	4	0	2	3	1	-1	0	1	1	-4	0	2	2	1.917	3.909
Non-Veget./Damaged (Veg 12)	-3	2	52	-2	0**	0	7	7	53	33	6	1**	-1	-3	-1	-2	-1	1	1	-2	0	-4	-1	-2	-3	-1	0	1	-4	-2	0	0	0	0	3	0	3.75	13.449
Unknown (Veg 14)	1	1	-6	-3	-5	0	0	-1	-1	-1	-9	4	1	-11	-13	0	0	-3	-1	-1	-2	-2	0	0	2	2	1	-2	0	1	10	-6	0	1	1	0	-1.167	4.088

* Serves only as an index of the magnitude of typical variation. No probability implications!

** Inconsistant interpretation of the Vegetation Categories of Litter (Veg 6) and Damaged (Veg 12) may have resulted in over estimation of dead graminoid litter.

traffic from the staging area. Plots R1C and R2C were paired with the plots measuring the effect of the ramp and should have reflected normal (control) growth on the site. However, as the ramps tended to be too narrow for 2-way traffic, frequently people stepped off the ramp to allow oncoming traffic to pass, so that these plots were subjected to trampling.

The changes in vegetative cover for each of the transects is presented in Table 3.3.2. Visible impacts are summarized in Table 3.3.3.

3.3.4.1 Controlled Trampling

Transects V and VI were subjected to respectively 5 and 25 walks per day (Plate 3.3) for a total of 32 days or 160 walks on Transect V and 35 days or 875 walks on Transect VI (Table C.5).

Characteristics of the "hiker" are presented in Appendix C.6. In summary the probability of a plant being stepped on is approximately 25% so that an average of 215 "hits" may be expected for each location on Transect V, and approximately 40 "hits" may be expected for Transect VI. The surface configuration of the transects may have caused more or less frequent impacts. It was estimated that the pressure on the surface would not exceed approximately 730 g/cm^2 and would generally be in excess of 300 g/cm^2. As smooth soles were used the "cutting action" on the plants would be minimal, and these impacts should be considered as the minimal impacts to be expected from the two traffic intensities.

No visible impacts were observed on Transect VI (see Tables 3.3.3, Plate 3.3), and quantitative data in Table

Table 3.3.3
Visual Impact of Foot Traffic
High = H, Moderate = M, Low = L, None = N

Plot No	Mechanical Impact Before	Mechanical Impact After	Other Impacts Causes and Impacted Species
I 1	N	L	
2	N	L	
3 ✓	N	H	
4 ✓	N	H	
5 ✓	N	M	
II 1	N	N	
2	N	L	
3	N	L	
4 ✓	N	H	
5 ✓	N	M	
III 1	N	N	frost
2	N	L	
3 ✓	N	M	
4	N	L	
5 ✓	N	H	frost
IV 1 ✓	N	N	
2 ✓	N	N	
3	N	N	
4	N	N	
5	N	N	
V 1	N	M	Carex, Min.rosii
2	N	M	Pot. fruticosa
3	N	L	Pot. div., Danth., Festuca
4	N	L	Ant.alp., broadleaf herb
5	N	L	Carex
VI 1	N	N	
2	N	N	
3	N	N	
4	L	L	
5	N	N	
ST 1	N		
2	N		

✓ highlights impacted plots

Visual Impact of Foot Traffic (Continued)
(High = H, Low = L Name = N, Moderate = M

	Mechanical Impact Before	Mechanical Impact After	Other Impacts Causes and Impacted Species
R 1	N	N	but Aren. dried up, tall growth;
2	N	N	frost; Solidago, Grasses and Arenaria brown; Grassplant fallen in plot.
1C (4C)	N	L	Minuartia rossii, Lichens, Solidago; Minuartia brown following frost.
2C	N	L	Minuartia rossi, Gentiana
SPF1	N	N	Sedge chlorotic, Minuartia green; Festuca no growth; Several broadleaf herbs show minimal growth at end of year; some etiolated earlier.
SPF2	N	N	Sedge chlorotic, Solidago dwarfed and etiolated; Min. rossii chlorotic; Festuca dormant; some broadleaf emerged since, also Polyt.jun.
PF1	N	N	broadleaf emerged after release; some Festuca, Min. rossi, and Selaginella growth
PF2	N	N	Sedge extremely chlorotic; minimal growth of broad-leaves; some Solidago growth, white and rose colored, not green; some Polytrichum (and Min. rossii?) green. After: several broadleaved-herbs show dwarfed growth; Minuartia rossii dying back; no growth in Carex and Festuca (all dead?)

3.3.2 indicate changes corresponding to normal seasonal developments. Slight reductions in broadleaf cover and increased exposure of grass cover may be due in part to the effects of freezing. Moderate and low impacts were noted on the plots of Transect V. Quantitative changes in cover confirm these (-at this duration of treatment, limited-) observations. Substantial impact on Plot V-2 corresponded with considerable damage to shrubby cinquefoil. Rhizomatous and simple rooted plants appeared to follow lichens in terms of sensitivity to trampling, with bunch grasses that project upwards on micro hummocks being more susceptible than the grasses of the main canopy. An increased exposure of rock surfaces (boulders and stones) reflects the removal of some of the grass and broadleaf foliage. As much of the damaged woody stems of the shrubby cinquefoil remained in place, the reduction in broadleaf cover did not result in an increase in the Non-Vegetated/Damaged category.

Impacts from the 875 walks are low to moderate, and it appears that this traffic intensity is only slightly in excess of the tolerance of these ecosystems in dealing with considerate hikers.

3.3.4.2 Uncontrolled Trampling

Transects I and II, located across the area immediately in front of the cave (Plates 1.8, 2.1) were designed to intercept damage from high activity associated with the filming. At peak activity well in excess of 100 people were on site (6). Also, fire pits were located within the area of maximum activity. The protective bottoms of some of these pits were insufficient to prevent direct heat damage to the underlying vegetation (Plates 3.4a,b), adding to the damage from trampling. It is likely that vegetation covered by any

object increases in sensitivity with the duration of the covering. The high concentrations of mineral salts in ashes may locally inhibit regrowth of vegetation for some time.

Damage observed on the plots of the two transects ranged from low towards the margins of the film set areas to high in the areas of main activity (Plate 3.5). Moderate damage was associated with areas where support crews shuttled back and forth and where cast and filming personnel remained while waiting to go on set (Plates 3.7 a,b). Only the most remote plot (II-1) (Plate C.6.B,A) of these transects was judged free from impact. Impacts were most intense in the area between the cave and the first transect (Plate 3.6) and exceeded the degree of damage recorded on the plots (Plates C.1 to C.10). (Experimental revegetation plots were located here. This information will be presented in a future report). Locally all vegetation had been eliminated. The quantitative data of of Table 3.3.2 confirms the observations with large changes in the cover of broadleaved herbs and grasslike plants and large increases in the areas occupied by exposed boulders and stones, and/or Non-Vegetated Soil/Damaged Surfaces.

Plots ST1 and ST2 (Plates C.31, C.32) received more dispersed traffic of lower intensity. Damage to crustose and squamulose lichens and polytrichum mosses on soil was observed on plot ST2. Moderate impacts were recorded for plot ST1 (Plate 3.10), in which damage also occurred on some low plants, including alpine pussytoes and more sensitive grasses such as spike trisetum. Moss campion in this plot seemed little impacted.

Plots R1C and R2C (Plate C.36 to C.40) also received lower intensity foot traffic (Plate 3.14). These plots

differed from the previous plots and transects in that they represent a somewhat moister ecosystem, richer in broadleaved herbs including alpine pussytoes, spike-like goldenrod, sedges and dwarf mountain lupine, and bryophtes including cetraria species. Impacts on Plot R2C were negligible. The impact on R1C was primarily on crustose and squamulose lichens, cetraria species and pussytoes (Plate 3.11). As foliage had nearly fully developed, at the "Before" photograph and senescence had not yet affected the foliage "After", it is not expected that serious estimation errors were caused by the abundance of broadleaved species. Some reduction in the standing crop of graminoid straw was also observed and verified by the quantitative measurements. Similarly slight increases in the exposure of boulders and soil surface occurred.

3.3.5 EFFECTS OF SHADING

Exclusion of sunlight affects not only photosynthetic activity, but also soil -, tissue -, and air temperatures to which the plant is subjected. Indirectly, also humidity of the air, evaporation and transpiration, and therefore soil moisture is affected. Hence the vegetation responses observed should not be regarded as a simple measure of the light requirement (or shade tolerance) of species, but as a response to a modified environment with the added stress of absence or reduction of light.

The effects of complete shading were to be determined on Transect I (ST1 and ST2 were modified; see section 3.3.4.2). Partial shading was to be observed on paired plots R1 and R2 with adjacent controls (R1c, R2c) (Plate 2.7).

The impacts of these treatments can be assessed only over several growing seasons. In this first season only the amount of growth and the apparent health of the vegetation can be assessed. Survival of the plant is affected by the amount of food reserves in the roots and the resistance to possible adverse conditions in subsequent growing seasons. To determine if frost and physiological shock following sudden exposure to the elements is a critical factor additional paired plots (PF and SPF) were located in areas previously covered by respectively the cave and the staging platforms. The vegetation on these plots is initially similar to that of Transect I. (In 1985 three additional plots, G85, were located in the area covered by a separate platform adjacent to the staging area, to document the development of what appeared to be a particularly severe impact on the vegetative cover). In this report the immediate effects evident at the end of the season of treatment is addressed/ PF, SPF and G85 plots will be analysed in subsequent reports.

3.3.5.1 Complete Shading

Transect III was enclosed completely by the cave shell. Within this shell a platform varied in height above the soil-surface from approximately 40 cm to 90 cm, leaving a relatively large airspace in between. However, the shell was continuous to the ground, and air circulation underneath the platform floor was minimal. The cave shell was positioned early in June (Table C.4) prior to any phenologic activity.

Transect III (Plates C.8.11 to C.8.15) differs significantly from the other transects with regard to the two dominant components: Broadleaved Herbs and Total Graminoid Herbs (Table 3.3.1).

It is relatively rich in broadleaved plants, particularly alpine pussytoes, while its mean grass cover is lower than that of the other transects.

Upon removal of the cave shell and the platform observed growth was sparse (Plates 3.6, 3.7, 3.8, 3.9, 3.10), consisting primarily of highly chlorotic and etiolated (Plate 3.12) California oatgrass. Broadleaf plants were only in initial stages of development, and displayed etiolation and a near-white (leucoplast) color. Minimal growth of grasses and broadleaved plants had occurred and decay of standing crop of grass straw had progressed exposing to a greater extent the underlying bryophyte layer. Sedges appeared to have remained dormant.

Between the period of removal of the cave and platform and the date of observation, respectively August 16-9 and September 6, greening of chlorotic plants and limited growth and development of the foliage of fescue and California oatgrass was observed. No growth was observed on sedges, and no flowers or seeds were observed.

It is difficult to support these observations with the quantitative data (Table 3.3.2), as following removal of the cave and the platform, the area was thoroughly raked to remove debris and foreign materials. As a result a substantial reduction occurred in the graminoid cover and the abundance of alpine pussytoes had been reduced. It is not possible to determine at this stage which of the plants remained dormant, and which may have died. For the plants that displayed activity, much of the growth will have been through the utilization of the food reserves in the roots. It will remain to be determined if sufficient reserves were established for successful survival in subsequent years.

The SPF plots (Plate 3.12) located under the staging area platforms reflected somewhat more activity, although the general observations of the Transect III plots apply. Firstly the staging area platforms were open towards the sides. This allowed some light to enter, and permitted more air circulation. It is therefore expected that favorable temperatures were reached earlier, but that the humidity and soil moisture would be lower than under the cave platform. The spacing between the staging platform and the ground surface was considerably less, estimated to range from near 0 cm to 30 cm, possibly resulting in pockets of low light and air circulation.

3.3.5.2 Partial Shading

Paired plots R1, R1C and R2, R2C (Plates C.8.35, C.8.36) were installed to observe the impacts of a walking ramp on the vegetation underneath (Plate 3.13). The plots were located in an area of snow accumulation slightly towards the lee side of the crest of the ridge, and the vegetation reflected greater moisture availability. The vegetation communities were distinctly richer in broadleaved plants, including yarrow, pussytoes, spike-like golden rod, field locoweed, showy Jacob's-ladder, and thread-leaved sandwort. Sedges were a more prominent component of the community. The grasses included alpine bluegrass as well as alpine fescue. Cetraria lichens were prominent in the understorey.

In comparison to the adjacent plots (R1C, R2C) growth underneath the ramp was greatly increased (Plate 3.14). Foliage of grasses was long and somewhat more "tender", and extended through the openings between the boards. Where the stringers of the ramp rested on the ground surface plant

growth was affected. The plants appeared chlorotic, etiolated and contorted and phenological development was limited.

At the time of removal of the ramp (See Table C.4) the ramp segments were propped up on one side so that it casted (partial) shade over the previously protected area. The vegetation was hardened off in this manner for 2 days. The incidence of frost shortly after the removal of the ramps particularly affected the vegetation previously under the ramps (Plate 3.15). The vegetation of the exposed plots (R1C, R2C) and of the surrounding area did not appear to be affected.

The protective ramp appears to enhance the growth of vegetation. Reduced evaporation due to shading and protection from desiccating wind, and possibly somewhat of a "cold frame" effect may be involved. (The latter will be further evaluated later in this report, integrating the soil temperature data with this information). Partial screening of ultra-violet-rich light may further have enhanced growth. The protective influences of the ramp render the vegetation more susceptible to injury from freezing temperatures.

The vigorous growth of broadleaved plants is confirmed quantitatively in Table 3.3.2. Whereas slight reductions in cover occurred in the control plots as a result of low impacts from trampling, the cover of broadleaved species increased greatly. Due to the late melting of the snow drifts, growth of the plots started late, and most growth occurred after the initial data collection. The increased broadleaved cover is likely to have masked the surface of exposed boulders and some of the growth of low-growing species, including sedges, fescue, and other grasses and bryophytes.

3.3.6 TREATMENT EFFECTS ON TRANSECT VEGETATION

The analysis of variance of the pre-treatment vegetation of the transects indicated that significant differences existed in the cover categories between the transects. As the proportions of the dominant vegetation were consistant, the vegetation is interpreted to represent different variants of the same vegetation type. The paired plots associated with the ramp study represented a distinct vegetative type.

A two-way analysis of variance (GLM, SAS 82.4) was applied to determine if the treatment effects were significant, and differed from transect to transect (variant to variant). Table 3.3.4 represents the results of this analysis. Least Square Means (LSM) for each of the treatments are presented to demonstrate the magnitude of the differences between the "Transect-Treatment" cells. Least Square Means represent the expected sub-group mean, corrected by holding the covariates on their average value. The LSM may differ from the actual observed mean.

Differences in broadleaved herb cover between the transects are not significant, although various treatments affected this cover significantly. The differences in effects cannot be attributed to differences in response to treatment due to differences in site quality (interaction of Treatment (=Time) and Transect). The Least Square Means of percent cover present the expected mean value for the given cell. For example the amount of damage is outweighed by the amount of growth for broadleaved-herbs. This "trend" is probably due to higher occurrence of light to moderately damaged plots than intensively damaged plots. In the latter one would expect broadleaved vegetation to be more vulnerable (20).

Table 3.3.4
Analysis[1] of Variance of Treatment Effects on Transect Vegetation

	Broadleaf Herbs	Graminoid Herbs	Bryophytes	Exposed Rock	Unvegetated Soil
GLM: Sign. Level					
Model	94.2	99.9	95.5	99.99	99.99
Time	97.9 98.4	99.6 99.6	45.4 59.5	99.9 99.5	99.99 99.99
Transect	96.1 94.2	99.9 99.9	98.2 94.1	99.99 99.99	79.6 99.6
Time & Transect	38.8 38.8	95.7 95.7	77.9 77.9	79.5 79.5	99.98 99.98
Least Squares Mean % Cover					
Trans Time					
I B	16.00	67.00	2.00	0.40	5.00
A	12.50	77.50	1.00	0	4.00
D	12.67	49.67	3.67	7.00	22.00
II B	19.60	56.80	16.00	5.40	0
A	15.33	65.33	6.67	9.33	4.67
D	21.00	17.50	1.50	13.00	43.00
III B	26.00	47.20	2.80	0.20	4.00
A	11.67	59.33	13.33	0.67	5.67
D	12.00	63.00	1.00	0.50	2.50
IV B	23.80	59.20	5.60	0.20	3.00
A	20.00	62.80	7.40	0.20	2.80
D					
V B	16.20	72.40	0.20	0.20	3.20
A	6.00	83.00	0	3.67	1.33
D	14.50	74.50	0	2.00	1.00
VI B	14.60	66.40	0.40	1.00	4.00
A	11.80	69.40	0	2.00	2.80
D					
ALL B	19.37	61.50	4.50	1.23	3.27
A	12.88	69.56	4.73	2.64	3.54
D	N.EST.	N.EST.	N.EST.	N.EST.	N.EST.

[1] OS SAS 82.4 Type II and Type III hypotheses are tested where applicable.

LEGEND

——α =.05 significant
▬▬α =.01 significant
▬▬α =.001 significant

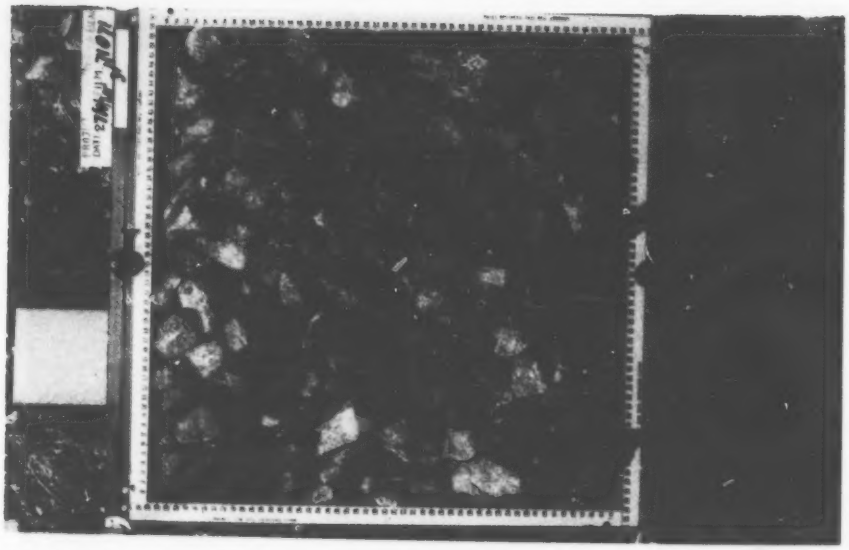
TIME = B - before treatment
A - after treatment
D - after treatment with visible damage

The analysis of variance was highly significant for the grass-like cover. Changes were strongly site TRANSECTS dependent and treatment (TIME) dependent. A significant part of the variation was due to the site responses to the treatments. It must be remembered though, that the treatments for the transects were not random, and the interaction has likely resulted from the selection of transects for specific treatments. Growth accounts for the consistant trend of increased cover between "Before" and "After" filming. The cover of grass-like vegetation is lower in most cases, reflecting the destructive impacts. However, in Transect III the LSM is estimated higher. This may be due to some late growth, and injury occurring primarily to the bryophytes.

Bryophyte coverage varied primarily by transects. Treatments generally did not have a significant impact. Changes in LSM for each of transects reflect the covering up of bryophytes by growing grass-like and broadleaved herbs, or, in the case of damaged areas, the increased exposure of the lower vegetation stratum.

Similarly the exposure of rocks increased significantly in the damaged transects.

The exposure of unvegetated soil surface also proved highly significant. The designation of the data was based on the visibility of impacts. Barren areas were clearly visible, and thus assigned to the damaged ("D") class. The dramatic increases in LSM's in the damaged class most directly indicate the degree of damage measured in each of the transects. It should be recognized that in some of the transects all plots were damaged, so that the maximum damage in the transect is likely to be much higher.



TP3
TP4
Soil Sampling
Area

Plate 3.4a

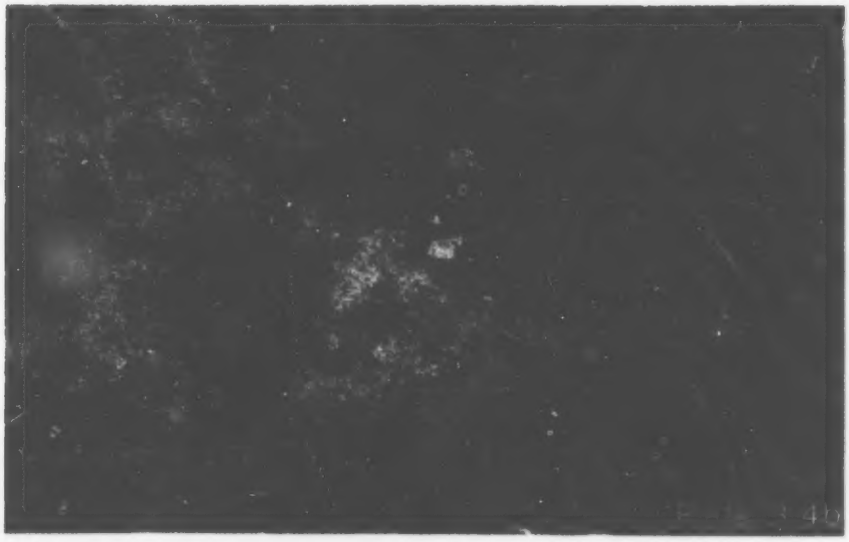


Plate 3.4b

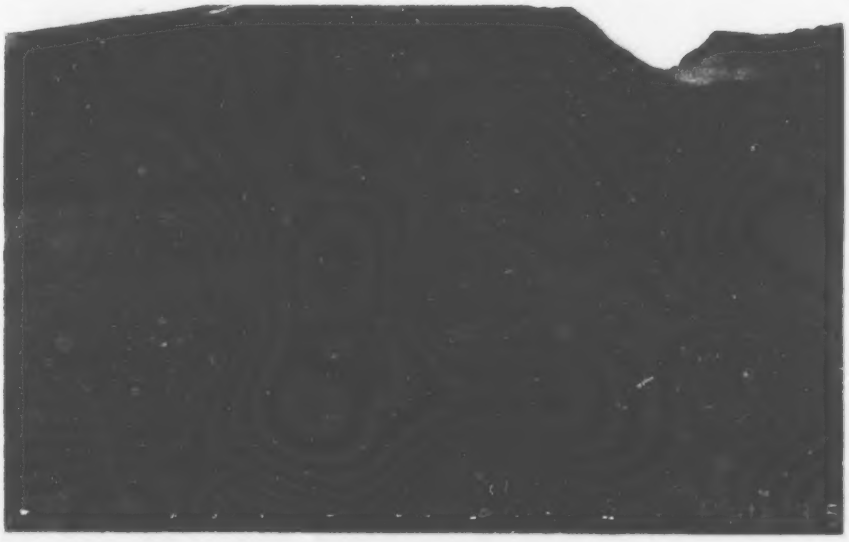


PLATE DESCRIPTION OF
PAGES 69, 70

Plate 3.1 A high component of Coarse Fragments (app. 70%) Reduced the Capacity of the Soil to Retain Water

Plate 3.2 On the South Slopes Wind and Early Snowmelt are responsible for Low Moisture Availability

Plate 3.3 Transects V and VI were subjected to respectively 875 and 160 Walks. The Soil Sampling Area served to study Soil Compaction

Plate 3.4 a) White Ashes mark the locations of Fire Pits lit for Filming

Plate 3.4 b) The Heat Conducted through the Protective Pit Bottoms was sufficient to Destroy the Underlying Vegetation. High Mineral Concentrations of the Ashes may Inhibit Regrowth

Plate 3.5 Trampling Damage in front of the Cave varies with the Intensity of Use, ranging from Severe to Light

PLATE DESCRIPTION OF
PAGES 73, 74

Plate 3.6 Severe Damage was Experienced in front of the Cave Mouth. (SD=Severe Damage, PF=Area previously under the Cave)

Plate 3.7 Moderate Damage was Experienced in Areas of continued Moderate Traffic. (SD=Severe Damage, MD=Moderate Damage, PF=Area previously under the Cave)

a) East of the Cave Mouth and
b) West of the Cave Mouth

Plate 3.8 Moderate to Severe Damage was Experienced in front of the Staging Platforms

Plate 3.9 Moderate to Severe Damage was Experienced in front of the Staging Platforms near Plot ST2

Plate 3.10 Damage to Broadleaved Plants and more tender Grasses of the Moist Area near Plot ST1. (SD=Severe Damage, MD=Moderate Damage, SPF=Area previously under Staging Platform)

Plate 3.6

Plate 3.7

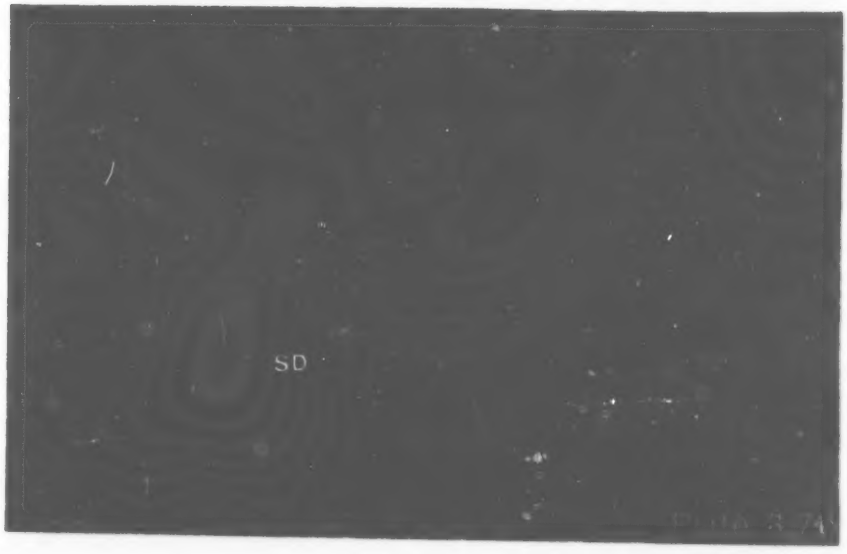


Plate 3.7A

Plate 3.8

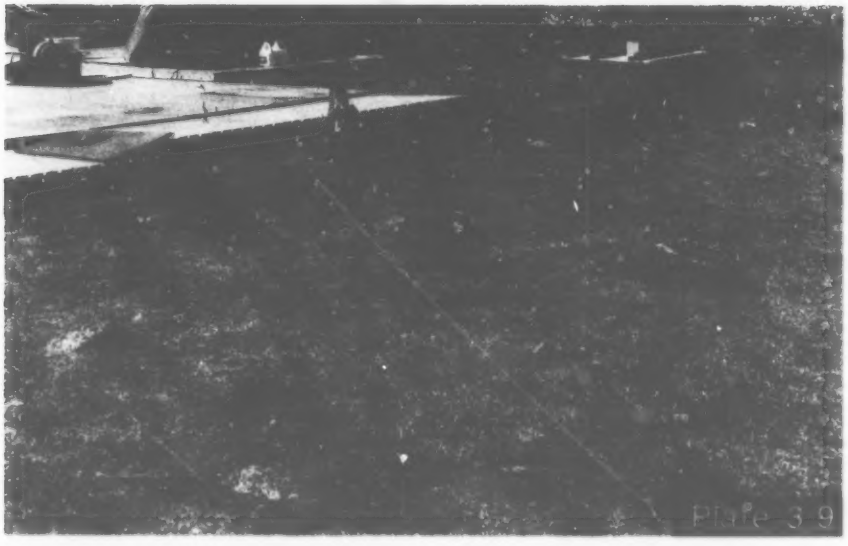


Plate 3.9

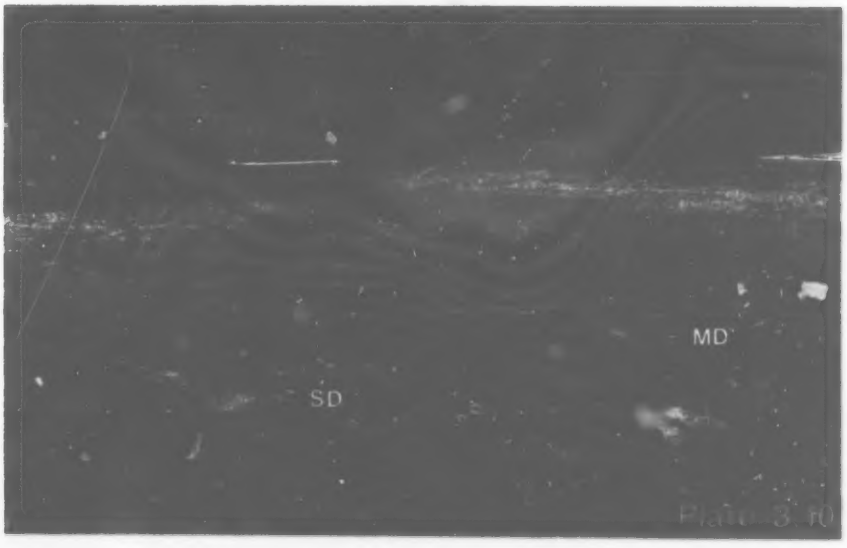


Plate 3.10

Plate 3.1

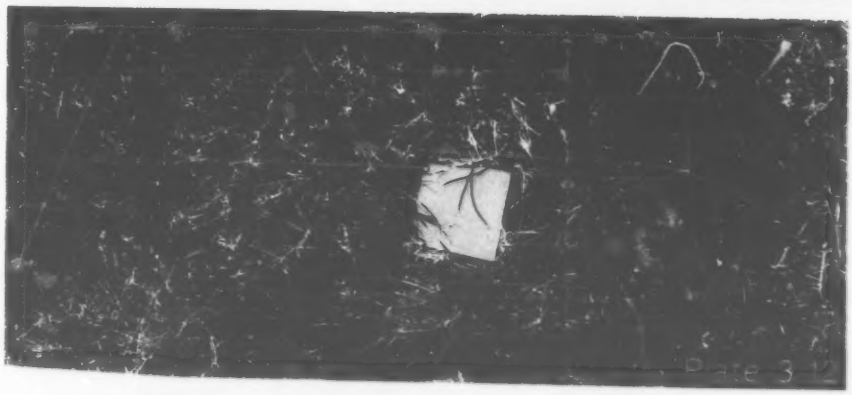


Plate 3.2

DP10
DP12
DP11

PLATE DESCRIPTION OF
PAGES 75, 76

Plate 3.11 Light Impacts occurred in Moister Vegetation Communities along the Ramp. Periglacial "Boulder Pavement" is more pronounced in these Areas

Plate 3.12 Sparse Growth of Chlorotic and Etiolated Grasses and Little or No Broadleaved Growth emerged from the Darkness under Cave and Staging Platforms. The Gray Standard provides a Reference

Plate 3.13 The Vegetation Grown under the Protection of the Ramp contrasts strongly with That grown in the Open, and That with some Trampling Damage to the Left of the Ramp. The Arrow Points towards the Location of the Plots (R)

Plate 3.14 Increased Growth underneath the Ramp, Open-grown Vegetation to the Right and somewhat-Trampled Vegetation to the Left occurred near the Plots. The Yellow and Blue Flags mark the Leads of Temperature Probes TP10, 11 and 12.

Plate 3.15 Freezing Temperatures affected the tender Vegetation previously protected under the Ramp

CHAPTER 4
Conclusions & Recommendations

CHAPTER FOUR
CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS AND RECOMMENDATIONS

At these early stages of the study the following conclusions and recommendations can be presented:

1) The growing season of 1984 was typical for the climatic conditions of this area, and the vegetation was not subjected to unusual environmental stress other than that documented in this study. Hence the findings of this study should be applicable to all similar areas.

2) The general regional climate of the area resembles that of the dry interior in many respects, but displays characteristics transitional to that of the adjacent Coast Mountains. Well-leached soils and an abundance of cetraria lichens and other plants are ecosystem indications of higher moisture availability. These conditions are characteristic of much of the area on the lee side of the Coast Mountains. The study findings should apply in these areas.

3) The study site is positioned altitudinally well below the tree line and the lower Krummholz line. However, local conditions of wind and cold air flows from higher altitudes cause a "near-alpine" environment typical of the parkland patterns of the lower components of the Krummholz subzone. (This subzone is considered part of the Subalpine zone by this author, while others consider it a part of the Alpine tundra zone).

4) Soils consist of shallow and very bouldery colluvium displaying evidence of past and presently active periglacial processes, including stone striping, frost

heaving and solifluction. The typical soil development is Sombric Humo-Ferric Podzol. The "Sombric" indicates long-term build-up of organic matter from grass roots and foliage in the upper parts of the soil. The Humo-Ferric Podzol indicates the "drier" end of a cool moist environment causing development of well-leached, acidified soils. The shallow soils represent the "Lithic" phase of the Bonnevier soils. Due to the high proportion of coarse stones and boulders in this soil, soil compaction does not readily occur, but the fine-fraction can erode from the coarse matrix.

5) Under most favorable conditions vegetation was not damaged by 50 footstep impacts, while 300 impacts caused moderate damage to the cover. Taking into consideration that conditions are usually far from optimum, that often hikers will walk more slowly, use smaller paces, and their shoe soles will tend to cause more damage. From these findings it is estimated that traffic intensity of greater than 150 footstep impacts is likely to cause damage under average conditions. Where less-favorable conditions exist, such as wet soils and slopes, causing unfavorable weight distribution, cutting effects and smaller steps (ie. probability of impact), the critical carrying capacity, preventing vegetation damage, may be considerably reduced. On favorable terrain and under favorable conditions up to approximately 750 passes per season will not cause significant impacts. Under more average conditions on favorable terrain 450 passes are thought to represent a practical limit. Unfavorable terrain and conditions may further reduce the carrying capacity to only fractions of these limits. Where traffic loads are in excess of these limits measures must be taken to control adverse impacts.

6) Severe damage to the vegetative cover has occurred in areas of concentrated traffic, in particular, set locations. In these areas the vegetative cover and the perennating plants parts have been nearly fully removed. Open fires on insulating trays in a few cases caused destruction of the underlying vegetation. The vegetation of severely damaged areas is not expected to recover. Severe damage was observed for an area in front and along the periphery of the cave.

Moderate damage occurred in areas of more dispersed traffic, generally bordering the preceding area as well as near the staging platforms. Much of the above ground biomass has been removed, and root systems and perennating plant parts are damaged. Slow recovery of the original vegetative cover is expected but may fail in specific locations, and weed invasion or erosion may take place.

Light damage from trampling was observed in areas of dispersed use, such as that bordering the moderately damaged areas and along the walking ramp. Damage occurs mainly to the above ground plant parts and some injury to perennating parts, possibly resulting in insufficient root reserves for subsequent years. It is expected that this vegetation will recover to nearly the original state over the next five years. Some sensitive species may be eliminated from the communities for a longer period of time.

It is recommended that the severely damaged area be revegetated and that this area be monitored for weed establishment, growth of planted (or seeded) species,

revegetated and that this area be monitored for weed establishment, growth of planted (or seeded) species, signs of erosion, and reactivation of periglacial processes. Recovery of the moderately-damaged areas should be carefully monitored. Where recovery is unsatisfactory or proceeds too slowly, replanting should be considered. Where erosion or periglacial activity becomes evident, revegetation must be undertaken.

7) The platforms and the ramp varied in effectiveness. It cannot yet be determined at this moment to what degree the vegetation underneath the platform has been affected by the period of darkness and low temperatures. From observations during the set-removal period it seems certain that severe trampling and damage from objects positioned directly on the ground would have significantly added to the above impacts (which may prove to be severe!), and would have increased the probability that the surface would be left prone to immediate erosion and possibly invasion by weeds.

The walking ramp proved effective in preventing trampling damage to the vegetation. However, due to its limited width people frequently stepped off the ramp to permit on-coming traffic to pass. This caused light to moderate damage immediately adjacent to the ramp. The stringers of the ramp were positioned directly on the ground affecting the growth of vegetation in those locations. Light damage to the vegetation of the ramp area also occurred due to early removal of the ramp during clean-up. A considerable amount of foot traffic and wheelbarrow use for moving materials from the cave area to the helicopter loading area occurred after removal of the ramp.

The growth of vegetation underneath the ramp was excessive. It can be attributed to increased moisture availability due to reduced evapotranspiration from wind and sun. As soil temperatures were somewhat lower than in the open, a "cold-frame effect" was not a factor. The rapidly-grown vegetation proved more sensitive to freezing. It is not known at this point if root reserves have been restored completely to permit normal growth in subsequent years.

It is recommended that ramps be modified for future use:

a) widen ramps to 122 cm or alternatively, position two ramps of 75 cm width for one-way traffic on each.

b) at 1 m intervals mount legs (blocks) under the stringers to minimize contact with the ground and allow passage of air (wind) underneath.

c) widen the spacing between boards to allow greater sun penetration. The spacing should probably be the maximum possible with regard to the traffic. The width of the boards, being approximately 8.8 cm, appears near-optimal.

Modified ramps should permit a better "hardening off" for the vegetation.

8) The exclusion of sunlight underneath the cave and staging platforms affect the growing conditions for the vegetation underneath by depressing air and soil temperatures below growth activity thresholds for a

significant period (shortening the growing season), maintaining higher humidity, and possibly promote growth of pathogens. These conditions largely prevented plant growth, caused severe etiolation and chlorosis in the few plants that became active, and possibly severely affected the root reserves of all plants. The bryophyte communities appeared more tolerant of these conditions. Platforms placed close to the ground appeared to have a more severe impact on the vegetation. The lack of air circulation may maximize the adverse effects.

9) Impacts on growth and survival of vegetation and its recovery cannot be determined immediately following the treatments. Depletion of root reserves, establishment of foreign plants (weeds) and regrowth can be quantified only after several growing seasons over which the effects become evident.

It is recommended that the areas impacted by the various treatments be monitored annually for the first 5 years, to detect problems early. Subsequent monitoring at every 5-year interval will establish recovery rates and degree of success.

The monitoring technique pioneered in this study is proving to be effective and relatively simple to apply. Precision of estimates can be improved by careful definition of vegetative categories and thorough training in plant recognition on photographic images through field observations, species mapping, and plant collection. The method lends itself to the study of communities or of species or even individual plants, but is limited in use for simple structured communities such as tundra, bunchgrass, revegetation and regeneration, pine grass, moss, and seeded pastures and reclamation sites.

10) The introduction of non-native species was prohibited as a condition of the park-use permit. The terminology was interpreted to refer to species native to the geographic region, without due regard for ecological different- iation. Materials from low-altitude bunchgrass ranges was introduced to "dress" the cave shell. These ranges have extensive disturbance histories and are carriers of seeds of varities of native and introduced species. The introduction of these seeds in the study area greatly increase the risk of weed establishment. Established weeds could be spread throughout the park by wind, wildlife and, particularly along the trails, by park users.

It is recommended that in future use-permits only seeds and live plant material may be introduced onto the use-site and/or transported in the park if they have been explicitly approved by the Parks Division. Approval would take into consideration, ecological compatibility and source history.

Establishment and growth of weeds will be determined in post-disturbance monitoring.

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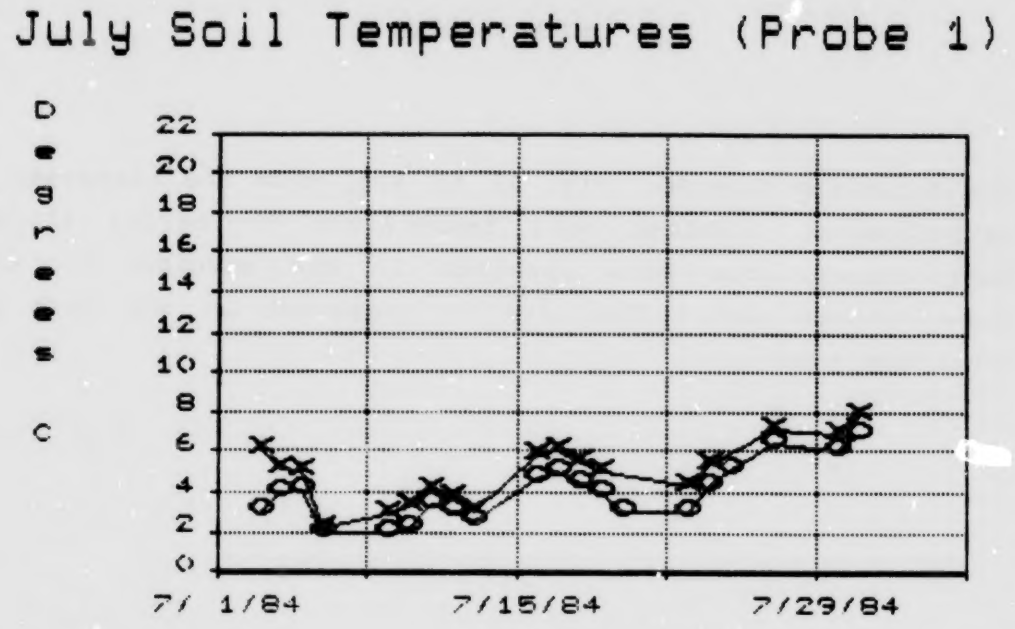
APPENDIX A
Soil Climate

APPENDIX A
SOIL CLIMATE

The following figures (Fig. A1 to A14) show the temperature variation at fourteen soil temperature monitoring sites. Soil temperatures were observed in the morning (0) and mid-afternoon (X). The date is presented on the base as month/day/year.



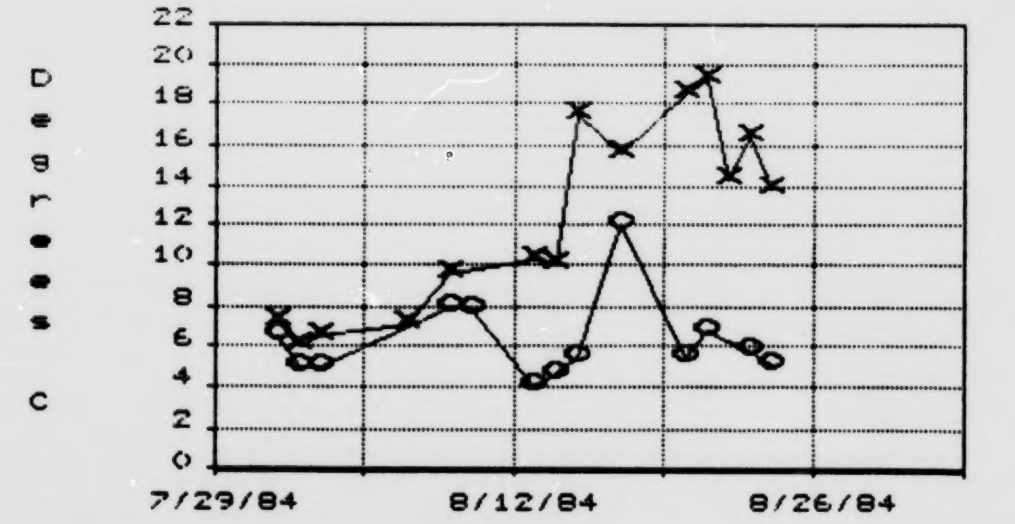


Figure A1 Under tent platform

July Soil Temperatures (Probe 2)

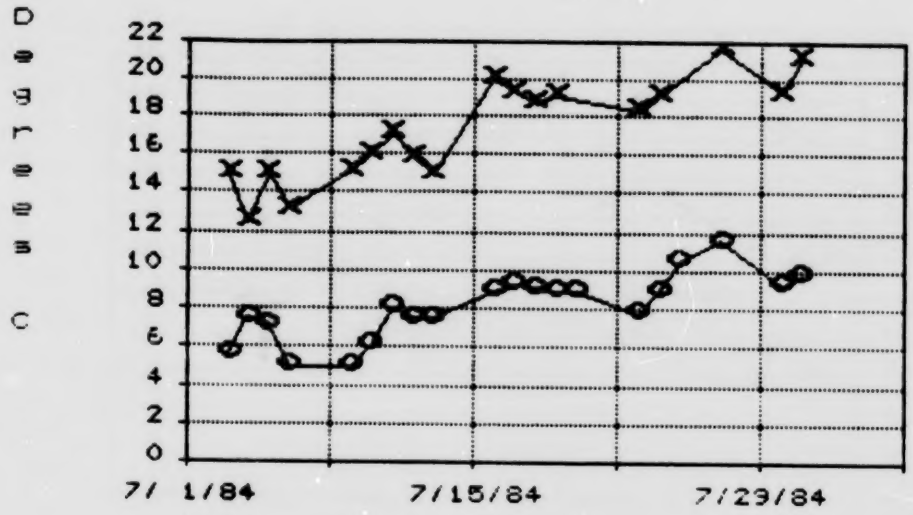


Figure A2 Moss covered area 10 m west of tent platform

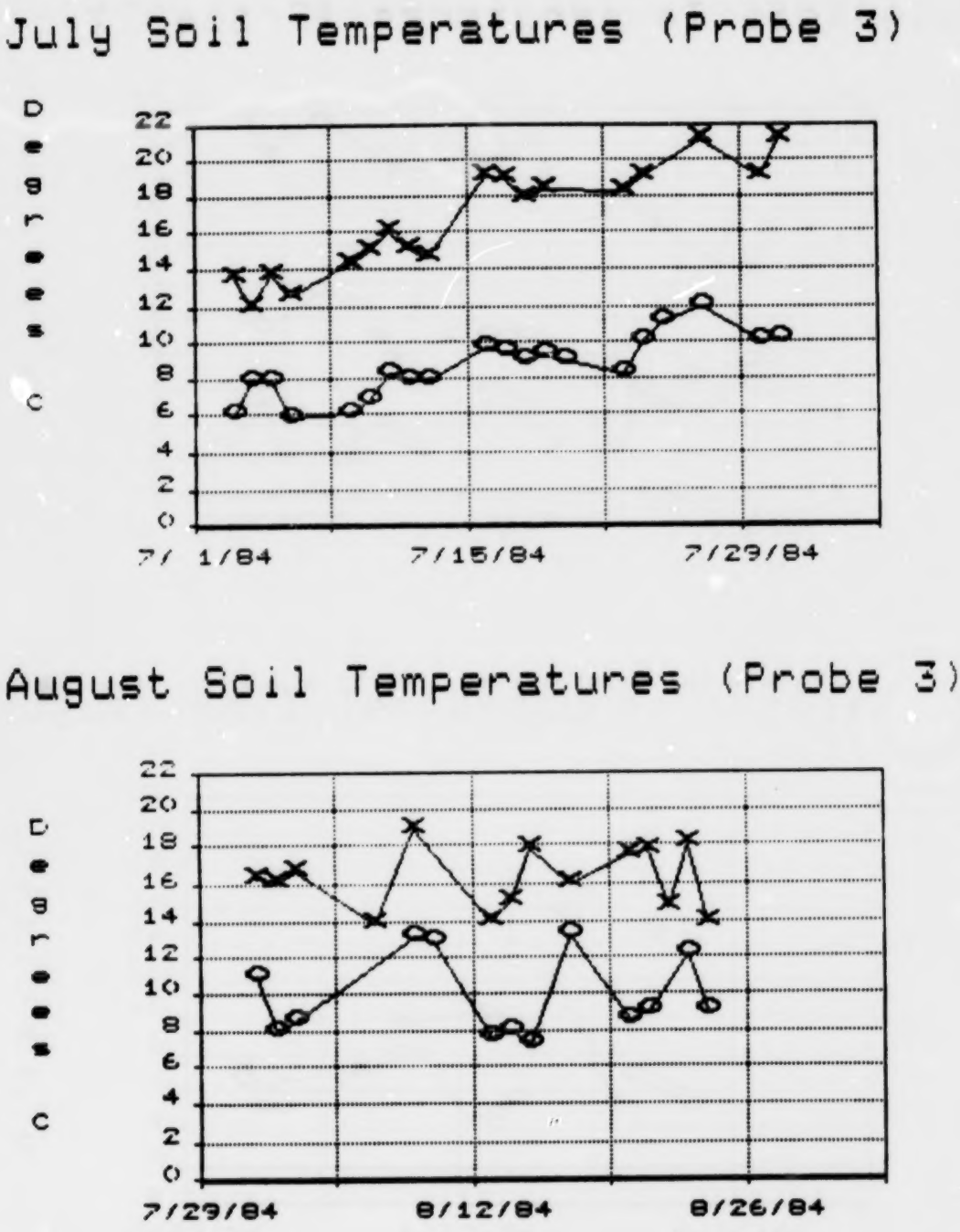
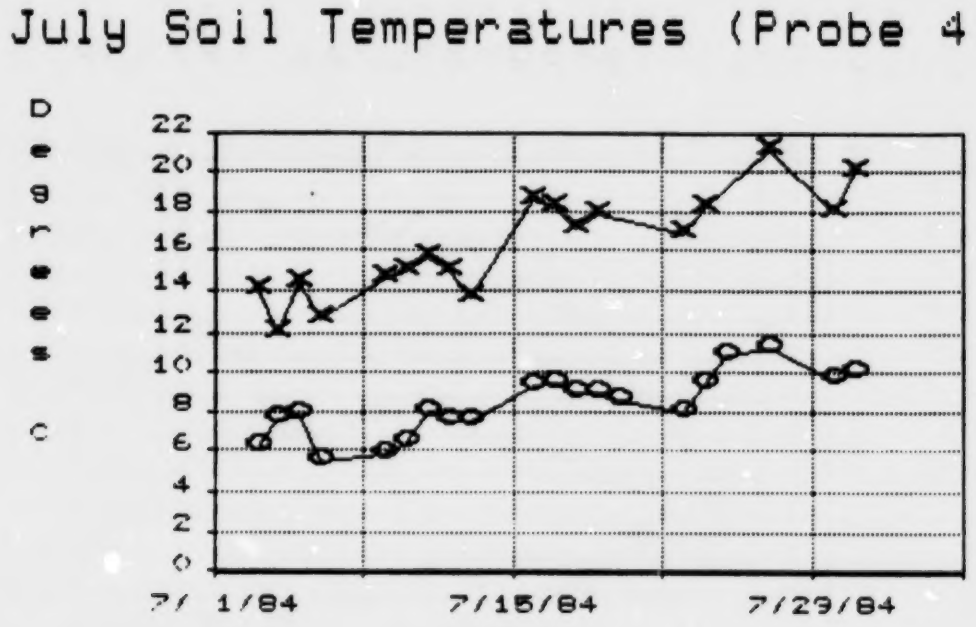


Figure A3 Grassy area of compaction test walk



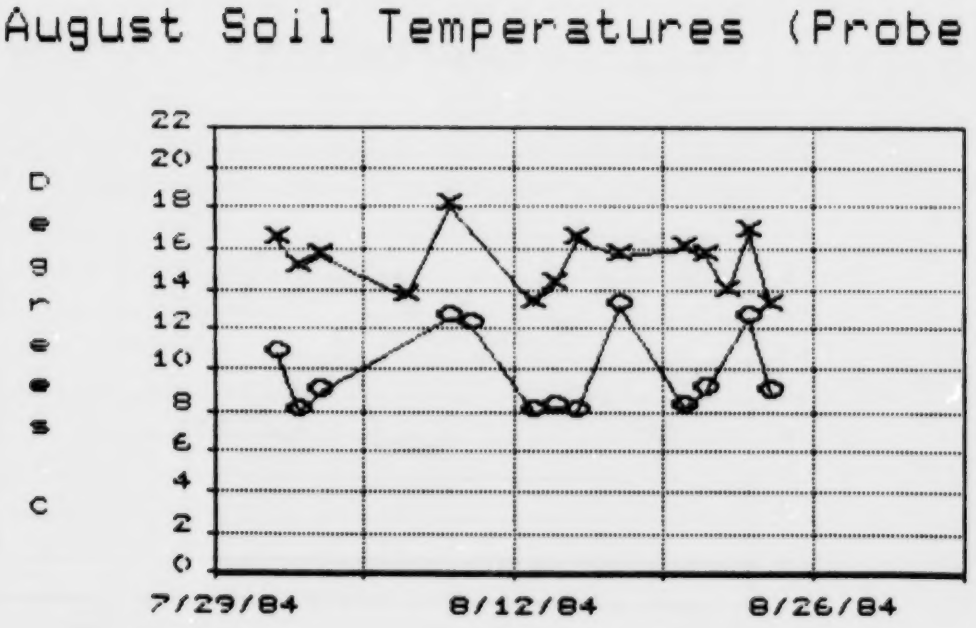
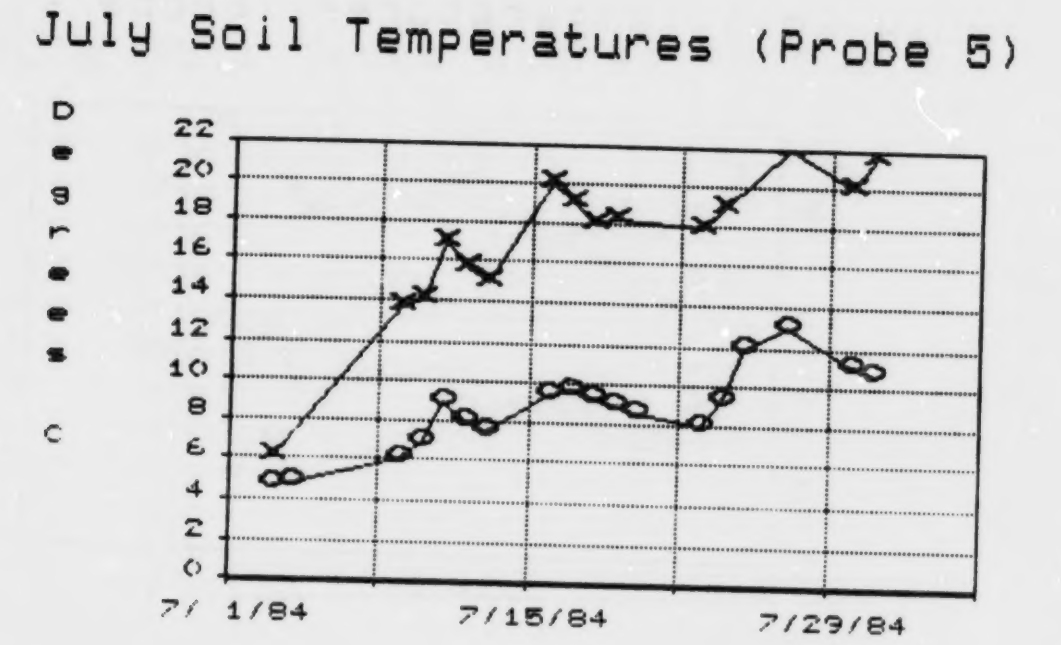


Figure A4 Bare area of compaction test walk



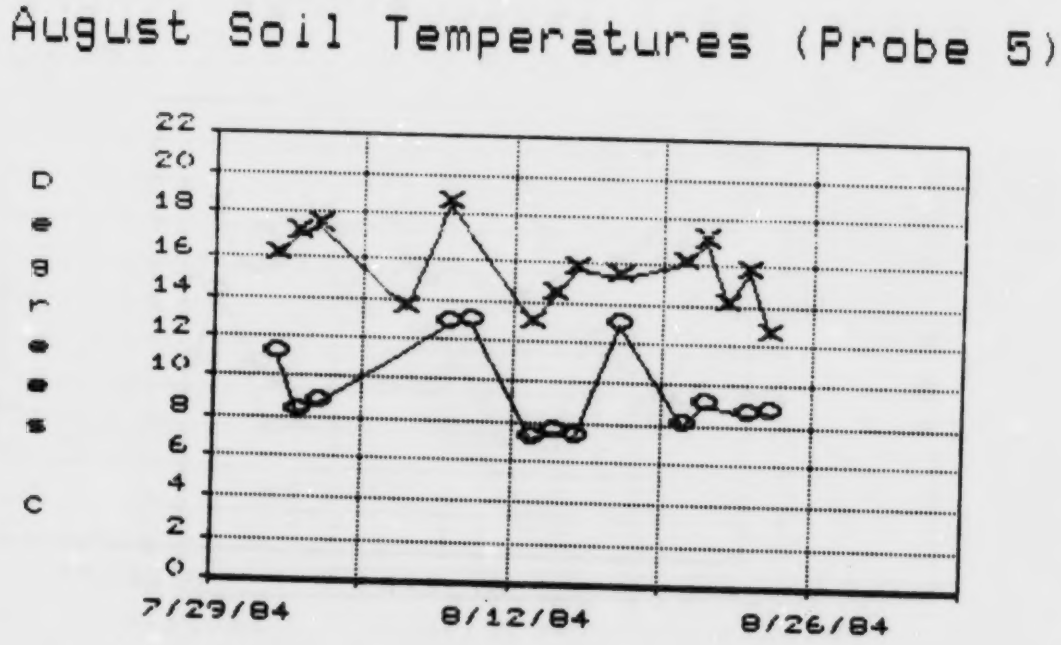


Figure A5 Open area east of tent platform

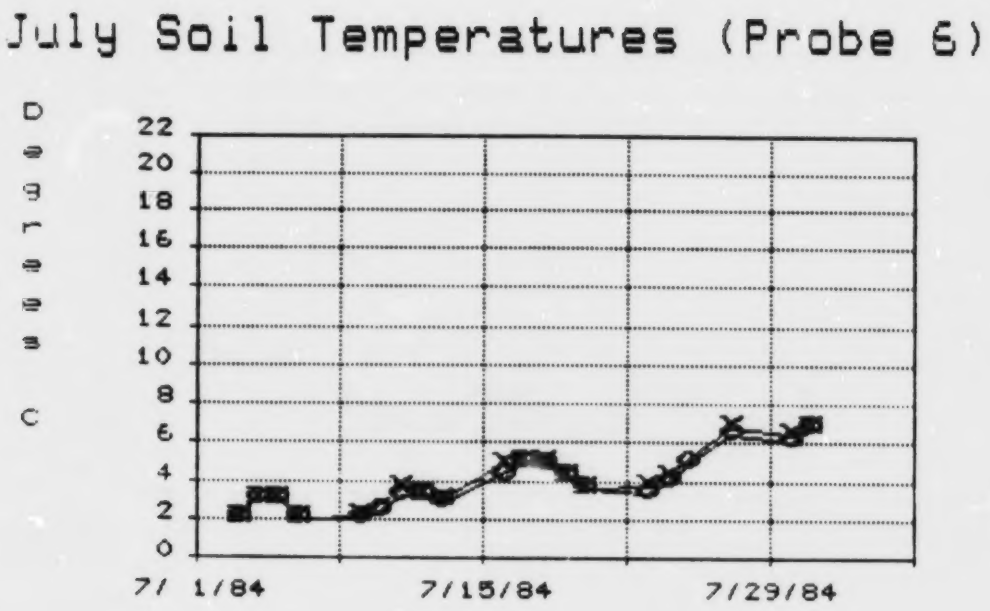
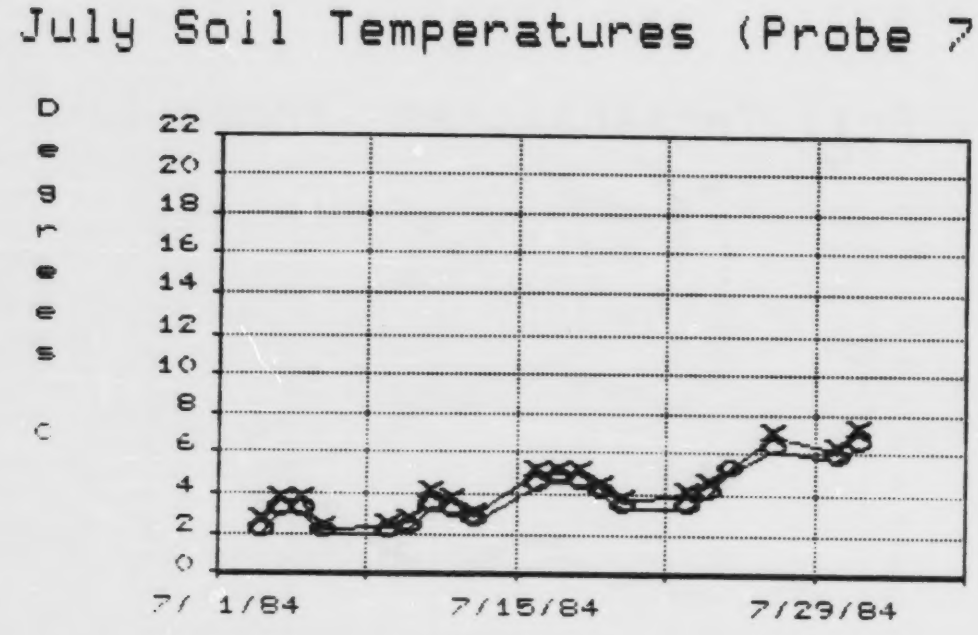


Figure A6 East end of cave



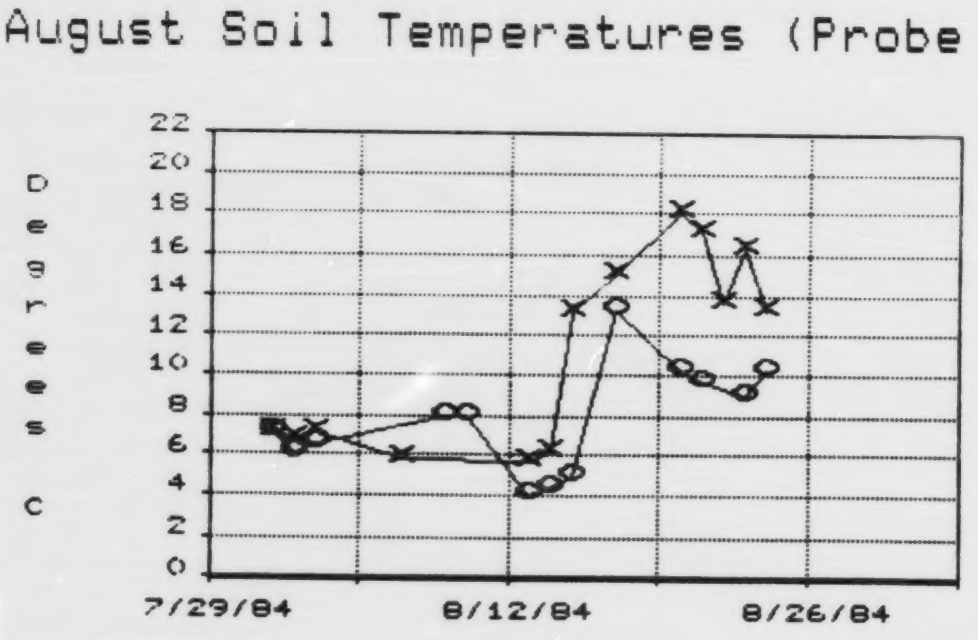
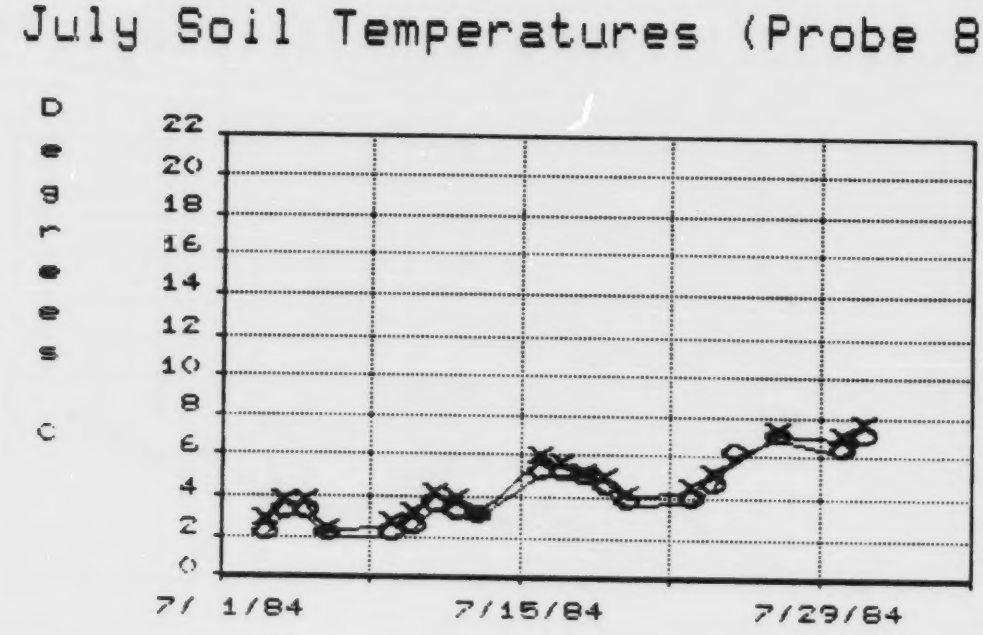


Figure A7 Cave centre



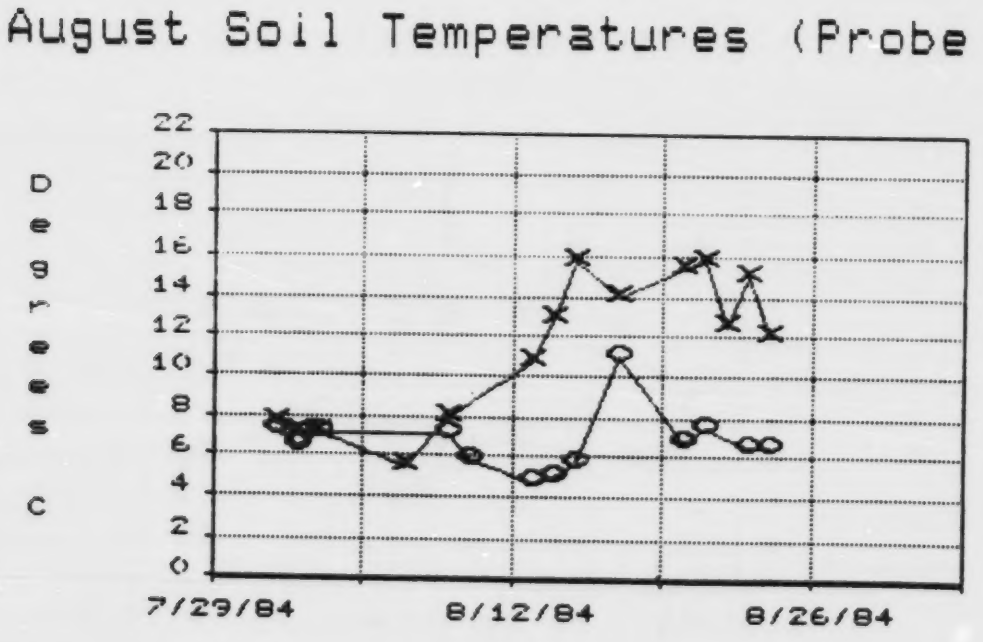
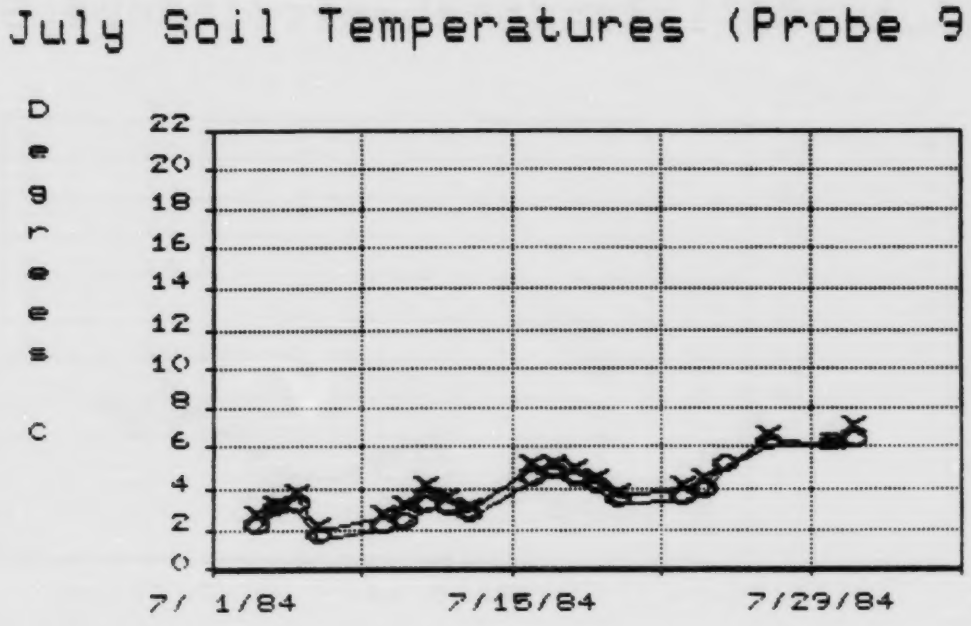


Figure A8 West end of cave



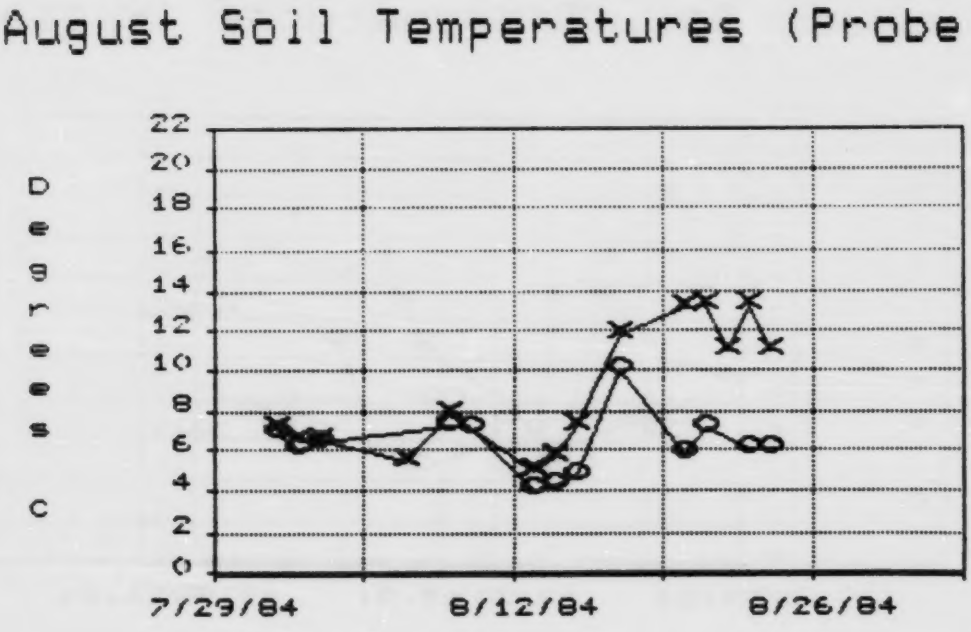
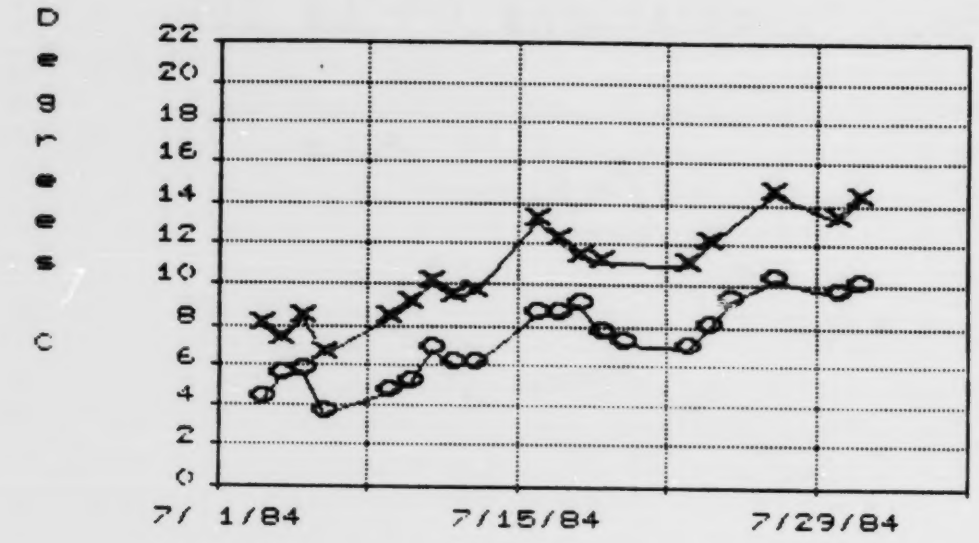


Figure A9 Centre front of cave



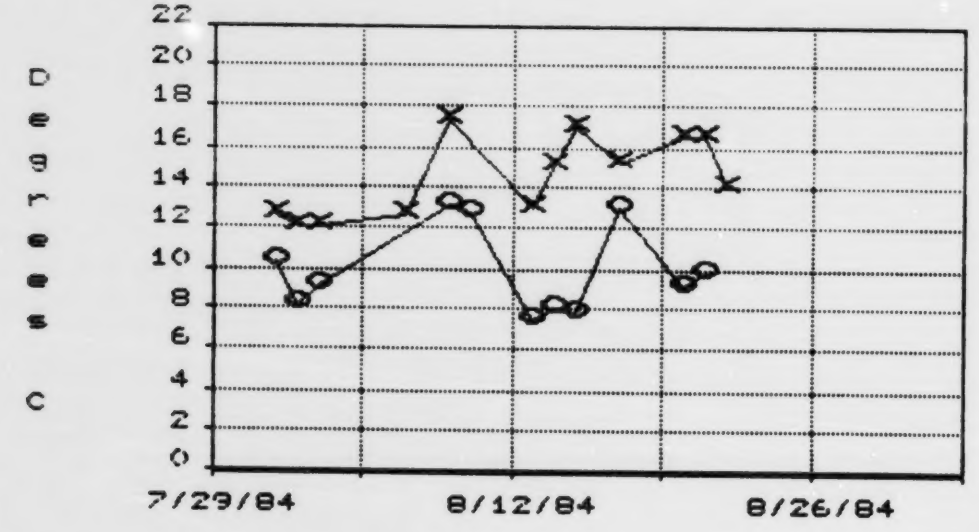


Figure A10 West end of walkway test site

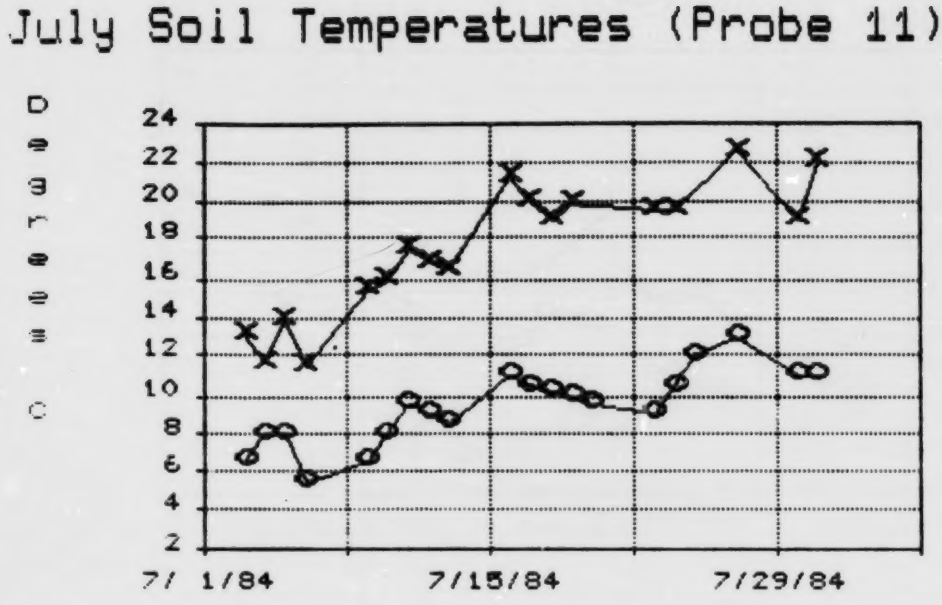


Figure A11 South (open) of walkway test site

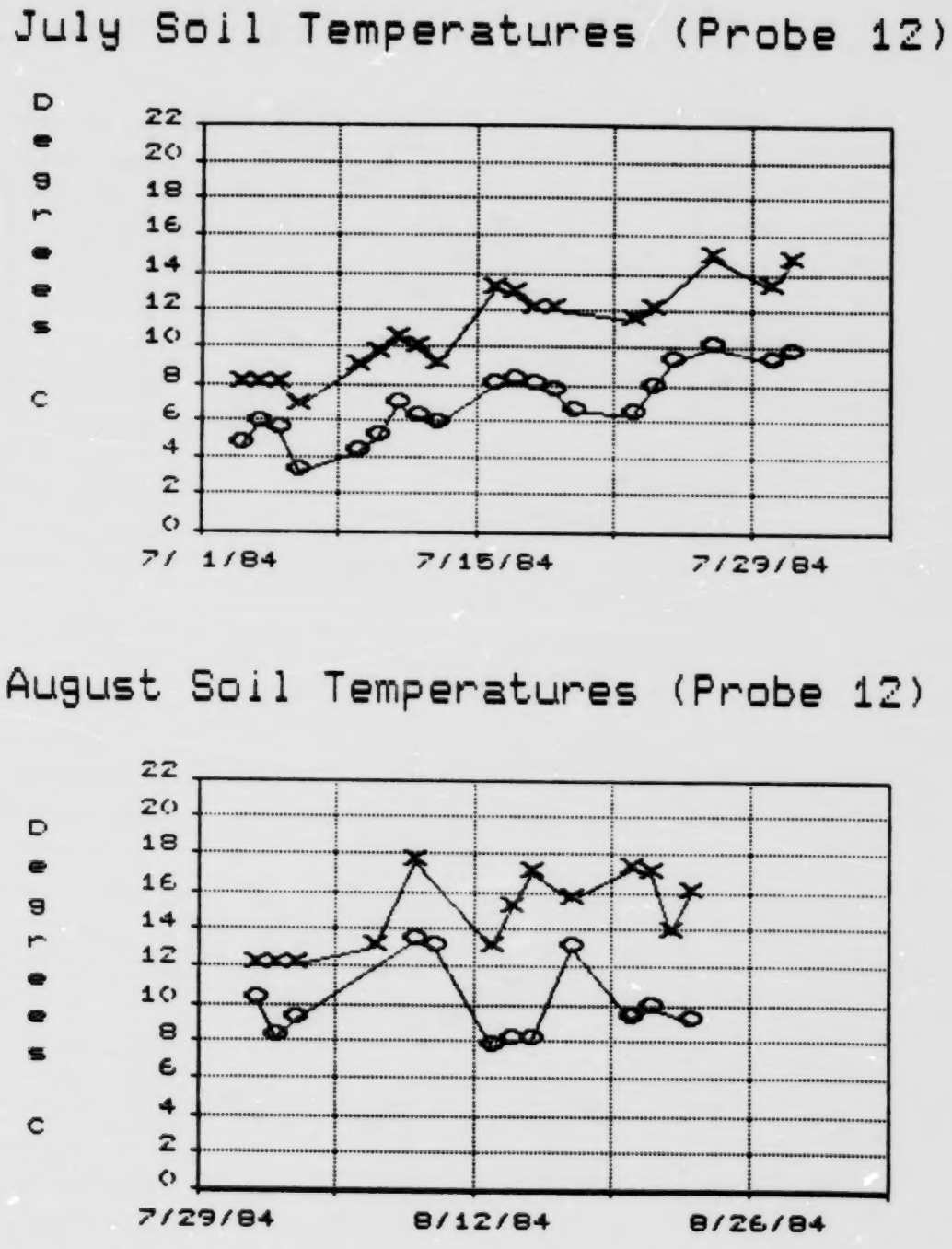
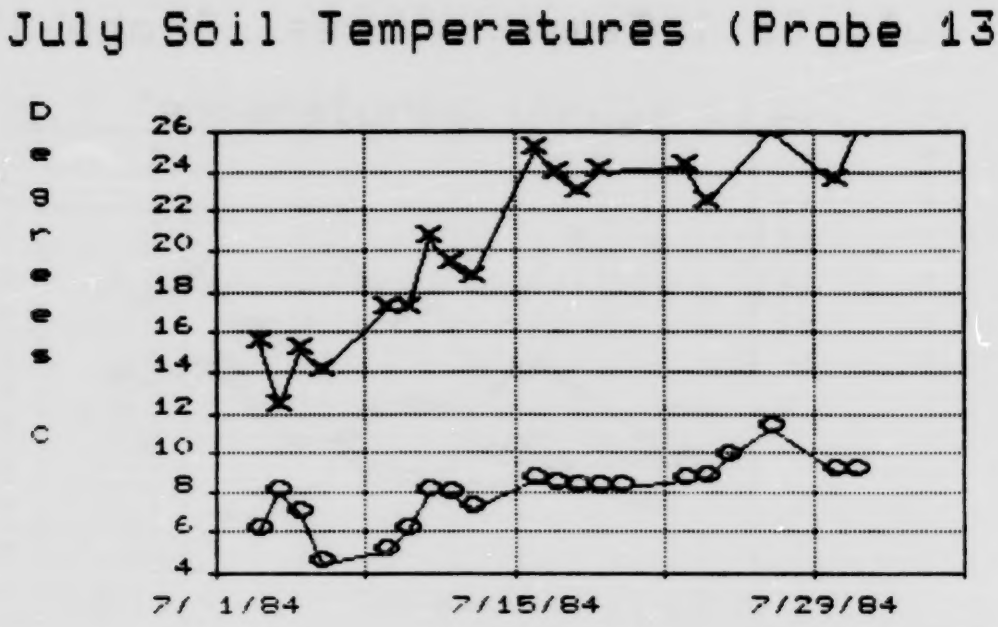


Figure A12 East end of walkway test site



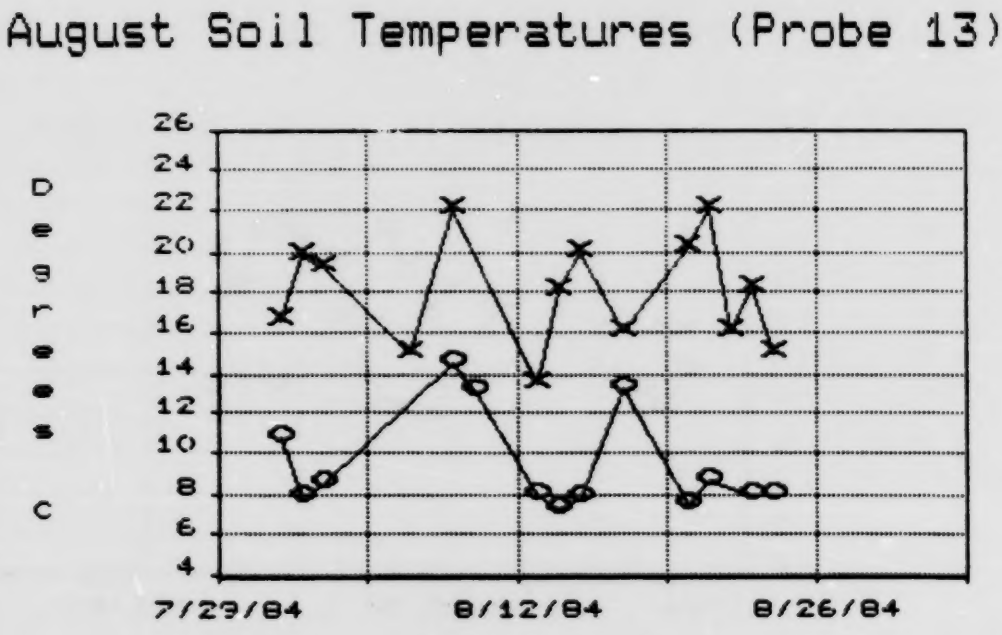
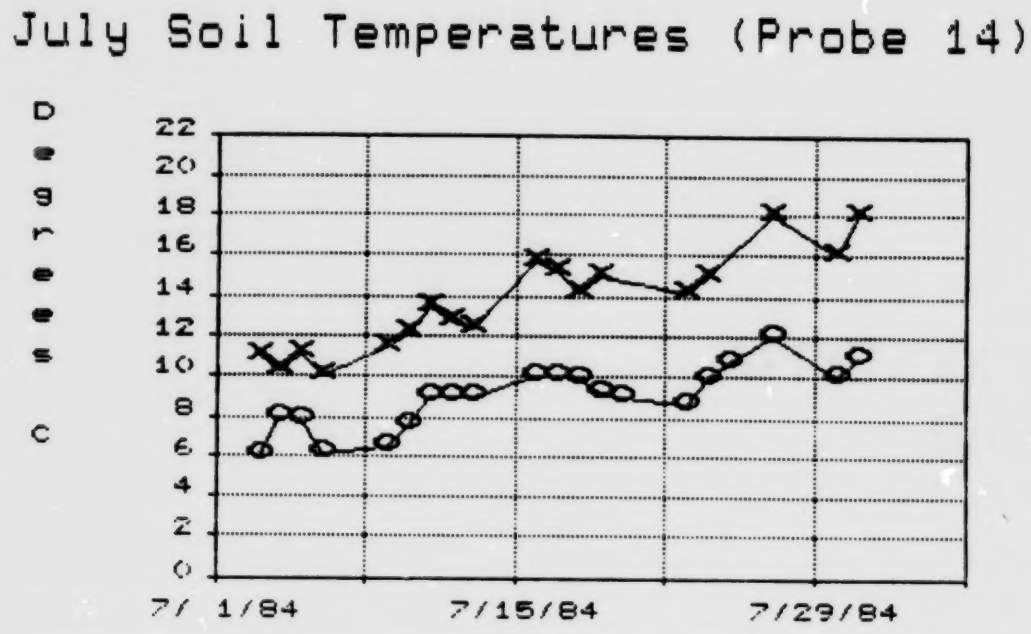


Figure A13 Dark moss covered soil at control site



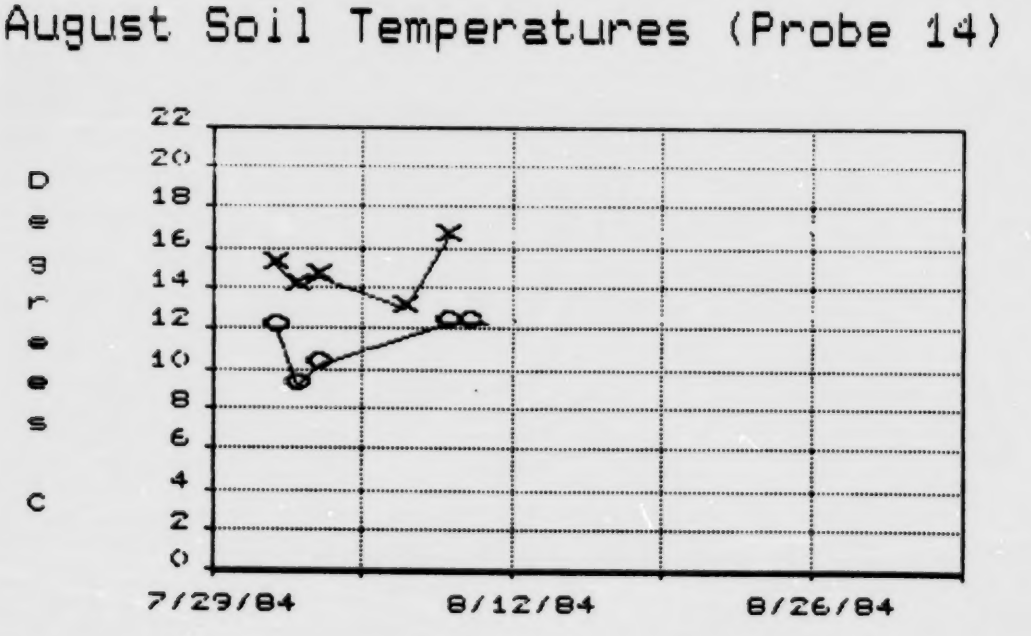


Figure A14 Grass covered soil at control site

APPENDIX B
Soils

PROJECT :PARKS-ALPINE SENSITIVITY
AGENCY : Ministry of Environment
SURVEYOR : Ron Kowall

FORM : 82-13507 SAMPLE RESULTS

HORIZON DATA LEVEL	LAB #	DESC	DEPTH	002 Ph-H2O	001 Ph-CaCl2	004 %H2O %	019 Excha-Ca Meq/100g	020 Excha-Mg Meq/100g	021 Excha-K Meq/100g	022 Excha-Na Meq/100g	017 CEC Meq/100g	024 Base-Sat %
A	84/1038	A	-	5.10	4.20	5.57	15.50	2.88	1.32	0.39	51.75	38.8
B	84/1039	A	-									
C	84/1040	A	-									
D	84/1041	A	-	5.10	4.20	3.73	9.60	1.50	0.88	0.38	35.30	35.0
E	84/1042	A	-									
F	84/1043	B	-	5.30	4.40	3.22	1.31	0.22	0.22	0.40	20.70	10.4

FORM : 82-13507 SAMPLE RESULTS

HORIZON DATA LEVEL	LAB #	DESC	DEPTH	005 C-L,WB %	008 Total-N %	007 C/N	169 Fe-Pyro %	170 Al-Pyro %	014 Avail-P Mg/Kg
A	84/1038	A	-	22.35	2.741	8.15			9.50
B	84/1039	A	-						
C	84/1040	A	-						
D	84/1041	A	-	13.87	0.496	27.96			7.37
E	84/1042	A	-						
F	84/1043	B	-	3.92	0.236	16.62	0.33	0.78	1.45

Appendix B.1.1

Table B.1.1 Standard Chemical Soil Analyses for Controlled Trampling: Soil Sampling Area. (BCMAF Soils Laboratory Test Method Dictionary)

12-MAR-85 FINAL REVIEW REPORT

PROJECT :PARKS-ALPINE SENSITIVITY
AGENCY : Ministry of Environment
SURVEYOR : Ron Kowall

FORM : 82-13507 SAMPLE RESULTS

HORIZON DATA LEVEL	LAB #	DESC	DEPTH	108 Bulk_D_3 g/cm3
A	84/1038	A	-	1.020
B	84/1039	A	-	0.894
C	84/1040	A	-	1.080
D	84/1041	A	-	0.783
E	84/1042	A	-	0.985
F	84/1043	B	-	

Appendix B.1.2

Table B.1.2 Bulk Densities for Controlled Trampling: After 25 walks/day, Transect V. A,B,C,D,E correspond to Plots 1,2,3,4, and 5 of Transect V,F corresponds to the Bf horizon of plot 5 (BCMAF. Soils Laboratory. Test Method Dictionary)

12-MAR-85

FINAL REVIEW REPORT

PROJECT :PARKS-ALPINE SENSITIVITY
AGENCY : Ministry of Environment
SURVEYOR : Ron Kowall

FORM : 82-13507

SAMPLE RESULTS

HORIZON DATA LEVEL	LAB #	DESC	DEPTH	076 Ps2.00mm %	084 Ps50.0um %	099 Ps2.0um %	093 Texture	095 ToT.Sand %	102 Silt %	103 ToT.Clay %	106 BULK-D-W g/cm3	222 Bulk-D-1 g/cm3	107 Bulk_D-2 g/cm3
A	84/1038	A	-								1.020	1.020	1.020
B	84/1039	A	-								0.894	0.894	0.894
C	84/1040	A	-								1.080	1.080	1.080
D	84/1041	A	-								0.783	0.783	0.783
E	84/1042	A	-								0.985	0.995	0.985
F	84/1043	B	-	100.00	54.26	6.32	SL	45.74	47.44	6.92			

Appendix B.1.3

Table B.1.3 Moisture Holding Capacities and Textural Composition of the Bf Horizon of Plot 5, and Bulk Densities for the Ah Horizons of Plots 1,2,3,4, and 5 of Controlled Trampling: Soil Sampling Area at the Beginning of the Study. A,B,C,D,E, and F correspond to resp. Ah of Plots 1,2,3,4, and 5 and the Bf horizon of plot 5. (BCMAF Soils Laboratory Test Method Dictionary)

02-APR-85 FINAL REVIEW REPORT

PROJECT :CLAN OF THE CAVE BEAR
AGENCY : Terrestrial Studies Branch
SURVEYOR : Phil Epp

FORM : 00-00176 SAMPLE RESULTS

HORIZON DATA LEVEL	LAB #	DESC	DEPTH	106 BULK-D-W g/cm3		222 Bulk-D-1 g/cm3	107 Bulk_D-2 g/cm3	108 Bulk_D_3 g/cm3
A	84/1856	A1	-		N	0.595	0.595	0.595
B	84/1857*	B1	-		N	1.581	1.581	1.581
C	84/1858*	C1	-		N	1.232	1.232	1.232
D	84/1859*	D1	-		N	0.668	0.668	0.668
E	84/1860*	E1	-		N	0.970	0.970	0.970
F	84/1861*	A2	-		N	0.604	0.604	0.604
G	84/1862*	B2	-		N.	0.658	0.658	0.658
H	84/1863*	C2	-		N	0.970	0.970	0.970
I	84/1864*	D2	-		N	0.598	0.598	0.598
J	84/1865*	E2	-		N	0.461	0.461	0.461

Appendix B.1.4

Table B.1.4 Bulk Densities of Controlled Trampling: Soil Sampling Area and Transect V (25 walks/day) after Treatment. A1, B1, C1, D1 and E1 correspond to Ah Horizons of Plots 1,2,3,4 and 5 of the Soil Sampling Area. A2, B2, C2, D2, and E2 correspond to Ah Horizons of Plots 1,2, 3,4, and 5 of Transect V. (BCMAF Soils Laboratory. Test Method Dictionary)

12-MAR-85

FINAL REVIEW REPORT

PROJECT :PARKS-ALPINE SENSITIVITY
AGENCY : Ministry of Environment
SURVEYOR : Ron Kowall

FORM : 82-13507

SAMPLE RESULTS

HORIZON DATA LEVEL	LAB #	DESC	DEPTH	123 W1500KPA %	124 W500KPA %	125 W100KPA %	126 W50KPA %	127 W33.3KPA %	128 W10KPA %	224 AWSC-R CM/M
A	84/1038	A	-	30.12*	37.12*	47.06*	49.26*	63.52*	89.38*	61.49
B	84/1039	A	-							
C	84/1040	A	-							
D	84/1041	A	-	26.47	32.16*	42.60*	44.20*	50.04*	78.87*	41.70
E	84/1042	A	-							
F	84/1043	B	-							

Appendix B.1.5

Table B.1.5 Moisture Holding Capacity and Available Water Storage Capacity for Ah Horizons for Plots 1 and 4 of Controlled Trampling: Soil Sampling Area. A,B,C,D,E, and F correspond to resp. Ah Horizons for Plots 1,2,3,4, and 5, and Bf Horizons for Test Method Dictionary)

Soil Textural Triangle

Appendix B.2

Legend

HC	-	heavy clay
C	-	clay
SiC	-	silty clay
SC	-	sandy clay
SiCL	-	silty clay loam
CL	-	clay loam
SCL	-	sandy clay loam
SiL	-	silt loam
L	-	loam
SL	-	sandy loam
LS	-	loamy sand
S	-	sand

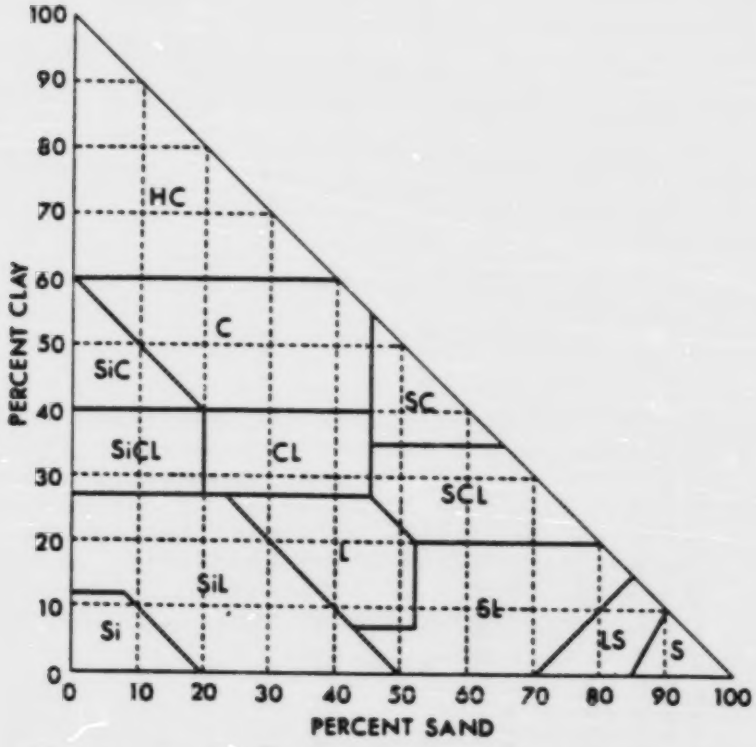


Fig B.2.1 Soil Texture Triangle Percentages of clay and sand in the main textural classes of soil; the remainder of each class is silt. Source: The Canadian System of Soil Classification, CSSC, 1978.

Appendix B.3.1 Soils Map and Legend of the Study Area (Kowall, 1985) at 1:50,000 Scale.

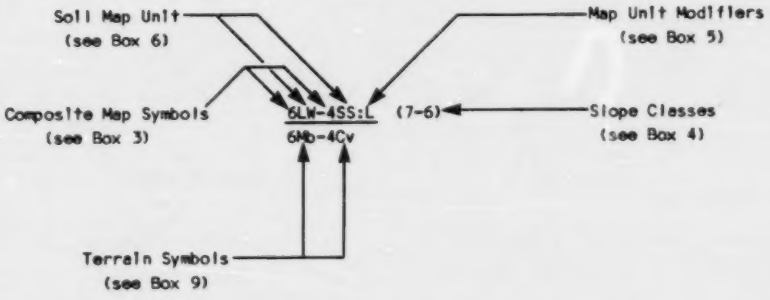
Figure B.3.1 Soils Map and Legend.

SOILS LEGEND FOR 92H/1

1. EXPLANATORY NOTES

The information in the following boxes explains the important characteristics of the soils of the Ashnola River map area (92H/1), which covers approximately 101,500 hectares in southwestern British Columbia near Keremeos. The soil mapping was done as part of the Ashnola Ungulate Biophysical project to provide more soils detail, especially in the more important wildlife habitat areas, as this map is to be used as a base for the wildlife capability mapping. The information presented in this map was derived from the Soils Map of the Princeton Area (Green et al., 1979) and by additional fieldwork and describes soils surveyed at an intensity level 4. Presentation scale is 1:50 000.

2. EXAMPLE OF MAP SYMBOL



Soil or landtype inclusions occupying 15 to 20% of the map unit are not usually identified unless they are strongly constrasting (such as rock outcrops, swamps, etc.).

3. COMPOSITE MAP SYMBOLS

Composite map symbols are used when two soils are intermixed or occupy such small areas that they cannot be separated at the scale of mapping. 6LW - 4SS:L signifies that 60% of the soil map unit is occupied by LW and 40% by SS:L.

4. SLOPE CLASSES*

Symbol Class	Percent Slope	Terminology	DESCRIPTION
1	0 - 0.5	level	gentle
2	0.5 - 2.5	nearly level	
3	2 - 5	very gentle slopes	
4	6 - 9	gentle slopes	moderate
5	10 - 15	moderate slopes	
6	16 - 30	strong slopes	
7	31 - 45	very strong slopes	steep
8	46 - 70	extreme slopes	
9	71 - 100	steep slopes	very steep
10	>100	very steep slopes	

Where a range of slope classes occur in a map unit the most dominant slope class is listed first and a dash (-) separates the slope classes. Where a portion of the area has a different slope from most of the unit a comma separates the slope class.

Examples:

7-6 slopes range from 16 to 45% within the area, 31 to 45% slopes dominate

3,7 most slopes range from 2 to 5%, a discrete lesser portion of the area has slopes ranging from 31 to 45%

* From CSSC, 1978.

5. MAP UNIT MODIFIERS

Symbol	Description
A*	acidic bedrock - granodiorite, granite, quartz diorite and gabbro
B*	basic bedrock - andesite, basalt, argillite and limestone
G**	soil map unit is composed of gleyed and/or gleysolic subgroups (a variation from the usual subgroup designation of the soil)
L**	soil map unit is composed of a lithic phase (depth of soil is between 10 and 100 cm to bedrock)

*From Rice, 1960; **from CSSC, 1978.

6. SOIL MAP UNIT DESCRIPTION

MAP SYMBOL	SOIL NAME	DIFFERENTIATING MAP UNIT CHARACTERISTICS						ACCESSORY MAP UNIT CHARACTERISTICS					
		BIOGEOCLIMATIC VEGETATION ZONES (see Box 7)	SOIL PARENT MATERIALS			SOIL DRAINAGE		ECOLOGICAL MOISTURE REGIME (see Box 12)	RANGE OF SLOPES (see Box 4)	BEDROCK GROUPING (see Box 5)	DEPTH OF MATERIAL	SOIL TAXONOMY (See Box 13)	ELEVATIONAL RANGE (metres)
			TEXTURE (see Box 8)		TERRAIN MATERIALS (see Box 9)	DOMINANT DRAINAGE (see Box 10)	DOMINANT PERVIOUSNESS (see Box 11)						
			Coarse Fragments	Fine Fraction									
A	Armstrong	IDF-MS: edaphic	moderate	mod. cse. to med.	moraine	good	moderate	xeric	steep - mod.	variable	> m	O.BL	915-1920
ASA	'ap	PPBG	variable	coarse	glacio-fluvial	good	rapid	xeric	steep	n/a	>1 m	E.EB	425-1220
BA	Barge Lake	MS	mod. - high	mod. cse.	colluvium	good	moderate	mesic	steep	variable	>1 m	O.DYB	1065-1920
BA:L	Barge Lake	MS	high	mod. cse.	colluvium	good	rapid - mod.	xeric	steep	variable	<1 m	O.DYB-lithic	1065-1920
BAA:L	Barkler	MS	high	mod. cse.	colluvium	good	rapid - mod.	xeric	steep	basic	<1 m	O.EB-lithic	1065-1920
BV	Bonnevier	AT	high	mod. cse.	colluvium	good	rapid - mod.	xeric	steep - mod.	variable	>1 m	O.SB	1980-2625
BV:L	Bonnevier	AT	high	mod. cse.	colluvium	good	rapid - mod.	xeric	steep - mod.	variable	<1 m	O.SB-lithic	1980-2625
CN	Connely	IDF	moderate	mod. cse. to med.	moraine	medium	moderate	mesic	steep	acidic	>1 m	O.GL (O.EB)	915-1690
CN:L	Connely	IDF	mod. - high	mod. cse. to med.	moraine	good	moderate	xeric	steep	acidic	<1 m	O.GL-lithic (O.EB-lithic)	915-1690
ET	Etches	MS-ESSF	n/a	n/a	organic	slow	moderate	hydric	gentle	n/a	>1 m	TY.M	1065-2255
FX	Ferroux	MS	variable	coarse	fluvial (fan)	good	rapid	xeric	mod. - steep	n/a	>1 m	O.DYB	1065-1690
GO	Gregoire	PPBG	moderate	mod. cse.	moraine	medium	moderate	mesic	steep	basic	>1 m	E.EB (O.GL)	425-1220
HE	Henning	MS	variable	coarse	glacio-fluvial	good	rapid	xeric	mod. - steep	n/a	>1 m	O.DYB	1065-1920
HL	Hellroarer	IDF	mod. - high	mod. cse.	colluvium	good	mod. - rapid	xeric	steep	acidic	>1 m	O.EB	915-1690
HL:L	Hellroarer	IDF	high	mod. cse.	colluvium	good	rapid	xeric	steep - very steep	acidic	<1 m	O.EB-lithic	915-1830

HR	Hester	PPBG	moderate	mod. cse.	colluvium	good	mod. - rapid	xeric	steep	basic	>1 m	O.EB	425-1220
HR:L	Hester	PPBG	high	mod. cse.	colluvium	good	rapid	xeric	steep - very steep	basic	<1 m	O.EB-lithic	425-1220
IL	Iltcoola	PPBG	variable	coarse	fluvial (plain)	good	rapid	xeric	gentle	n/a	>1 m	O.R	425-1220
KE	Kelowna	PPBG: edaphic	moderate	mod. to mod. cse.	moraine	good	moderate	xeric	steep	variable	>1 m	O.DB	425-1220
KG	Keogan	IDF	mod. - high	mod. cse.	colluvium	good	mod. - rapid	xeric	steep	basic	>1 m	E.EB	915-1690
KG:L	Keogan	IDF	high	mod. cse.	colluvium	good	rapid	xeric	steep - very steep	basic	<1 m	E.EB-lithic	915-1830
LW	Lawless	ESSF	mod. - high	mod. cse. to med.	moraine	medium	moderate	mesic	mod. - steep	variable	>1 m	O.HFP	1525-2255
LW:G	Lawless	ESSF	moderate	mod. cse. to med.	moraine	slow	moderate	hydric	moderate	variable	>1 m	GL.HFP (O.G)	1525-2255
LW:L	Lawless	ESSF	mod. - high	mod. cse. to med.	moraine	good	rapid - mod.	mesic	mod. - steep	variable	>1 m	O.HFP-lithic	1525-2255
LY	Lumby	IDF	variable	mod. cse. to med.	fluvial (fan)	good	moderate	mesic	mod. - steep	n/a	>1 m	O.EB	915-1690
MN	Marron	Variable	high	cse. to mod. cse.	colluvium (talus)	good	rapid	xeric	steep	n/a	>1 m	O.R	425-2625
MP	Mickie Plate	IDF-MS: edaphic	mod. - high	med. to mod. cse.	colluvium	good	moderate	xeric	steep - mod.	variable	>1 m	O.BL	915-1920
MP:L	Mickie Plate	IDF-MS: edaphic	high	med. to mod. cse.	colluvium	good	rapid - mod.	xeric	steep - mod.	variable	<1 m	O.BL-lithic	915-1920
PT	Pitin	ESSF-AT	mod. - high	mod. cse.	colluvium - moraine	medium	moderate	mesic	mod. - steep	variable	>1 m	SM.HFP(O.HFP)	1950-2255
PT:G	Pitin	ESSF-AT	mod. - high	mod. cse.	colluvium - moraine	slow	moderate	hydric	moderate	variable	>1 m	GLSM.HFP (O.HG)	1950-2255

PT:L	Pitin	ESSF-AT	high	mod. cse.	colluvium	good	mod. - rapid	xeric	steep - mod.	variable	<1 m	SM.HFP-ilthic	1950-2255
PY	Paseyten	ESSF	variable	coarse	glacio-fluvial	good	rapid	xeric	moderate	n/a	>1 m	O.HFP	1525-2255
R	Rutland	PPBG: edaphic	variable	coarse	glacio-fluvial	good	rapid	xeric	steep - mod.	n/a	>1 m	O.DB	425-1220
RF	Rockface	PPBG	moderate	mod. cse.	colluvium	good	mod. - rapid	xeric	steep	acidic	>1 m	O.EB	425-1220
RF:L	Rockface	PPBG	high	mod. cse.	colluvium	good	rapid	xeric	steep - very steep	acidic	<1 m	O.EB-ilthic	425-1220
RO:A	Rock Outcrop	Variable	n/a	n/a	bedrock	good	rapid	xeric	steep - very steep	acidic	n/a	N/A	425-2625
RO:B	Rock Outcrop	Variable	n/a	n/a	bedrock	good	rapid	xeric	steep - very steep	basic	n/a	N/A	425-2625
SA	Saunier	IDF-MS	variable	coarse	fluvial (plain)	good	rapid	xeric	moderate - gentle	n/a	>1 m	O.R	915-2255
SA:G	Saunier	IDF-MS	variable	coarse	fluvial (plain)	slow	rapid	hydric	gentle - mod.	n/a	>1 m	GL.R (O.G)	915-2255
SS	Skalst	ESSF	mod. - high	mod. cse.	colluvium	good	moderate	mesic	steep	variable	>1 m	O.HFP	1525-2255
SS:L	Skalst	ESSF	high	mod. cse.	colluvium	good	rapid-mod.	xeric	steep - mod.	variable	<1 m	O.HFP-ilthic	1525-2255
TR	Treheorne	IDF	variable	coarse	glacio-fluvial	good	rapid	xeric	steep	n/a	>1 m	E.EB	915-1690
TW	Tunkwa	IDF	moderate	mod. cse. to med.	moraine	medium	moderate	mesic	steep	basic	>1 m	O.GL (O.EB)	915-1690
TW:L	Tunkwa	IDF	mod. - high	mod. cse to med.	moraine	good	moderate	xeric	steep	basic	<1 m	O.GL-ilthic (O.EB-ilthic)	915-1690
WI	Wilbert	MS	mod. - high	mod. cse	moraine	medium	moderate	mesic	steep - mod.	variable	>1 m	O.DYB (BR.GL)	1065-1920
WI:G	Wilbert	MS	moderate	mod. cse.	moraine	slow	moderate	hydric	moderate	variable	>1 m	GL.DYB (O.G)	1065-1920
WI:L	Wilbert	MS	mod. - high	mod. cse.	moraine	good	rapid-mod.	xeric	steep - mod.	variable	>1 m	O.DYB-ilthic	1065-1920

7. BIOGEOCLIMATIC VEGETATION ZONES*

Symbol	Description
PPBG - edaphic	Areas of the Ponderosa Pine-Bunchgrass zone consisting of edaphic grassland vegetation on south and/or west facing slopes.
PPBG	Ponderosa Pine-Bunchgrass zone. Includes the lower interior Douglas-Fir zone (containing ponderosa pine).
IDF - edaphic	Areas of the interior Douglas-Fir zone consisting of edaphic grassland vegetation on south and/or west facing slopes.
IDF	Interior Douglas-Fir zone. Excludes the lower IDF zone containing ponderosa pine.
MS	Montane Spruce zone
ESSF	Engelmann Spruce - Subalpine Fir zone. Includes the parkland areas near the Alpine Tundra zone.
AT	Alpine Tundra zone

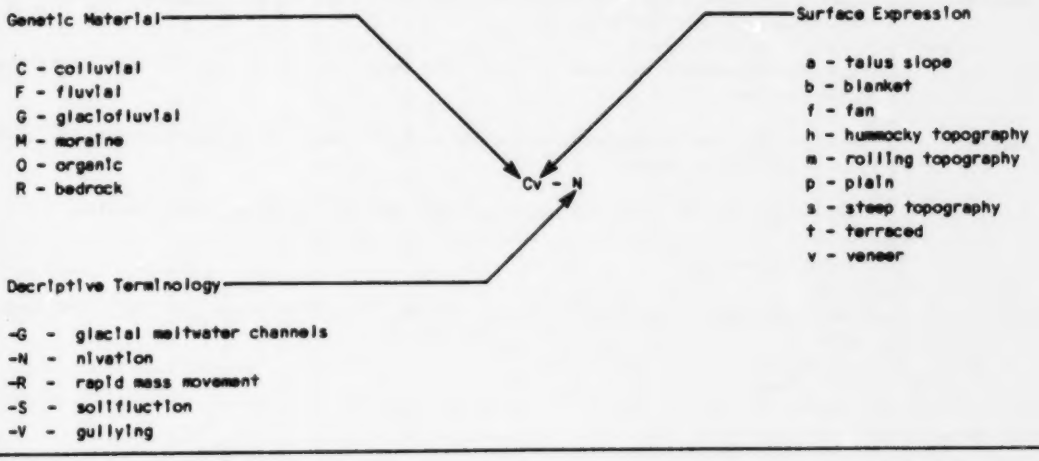
* From Mitchell et al., 1981.

8. TEXTURE AND COARSE FRAGMENT CONTENT*

Coarse Fragment Content (>2 mm)		Fine Fraction Texture (<2 mm)	
Class	Description	Class	Description
high	>50% of soil volume	coarse	sand, loamy sand
moderate	20 to 50% of soil volume	moderately coarse	sandy loam
low	<20% of soil volume	medium	loam, silt loam, silt
		moderately fine	clay loam, sandy clay loam, silty clay loam
		fine	sandy clay, silty clay, clay

* From CSSC, 1978.

9. TERRAIN CLASSIFICATION*



* From ELUC, 1976 and Ryder et al., 1983.

10. DRAINAGE*

Terminology	Description
good	soil holds little moisture after rain; no excess moisture for most of the year; consists of rapidly and well drained classes
medium	excess moisture for short but significant periods of the year; consists of moderately well and imperfectly drained classes
slow	excess moisture throughout the year; free water remains at or near the soil surface most of the year; consists of poorly and very poorly drained classes

* From CSSC, 1978.

11. PERVIOUSNESS*

Terminology	Description
rapid	the capacity to transmit water vertically is so great that the soil will remain wet for no more than a few hours after thorough wetting
moderate	the capacity to transmit water vertically is great enough that the soil will remain saturated for no more than a few days after thorough saturation
slow	the potential to transmit water vertically is so slow that the horizon or the soil will remain saturated for periods of a week or more after thorough wetting

* From CSSC, 1980.

12. ECOLOGICAL MOISTURE REGIME*

Terminology	Description
xeric	water removed extremely rapidly to rapidly in relation to supply; soil moist for negligible or short periods after precipitation; consisting of very xeric to subxeric classes
mesic	water readily to slowly removed in relation to supply; soil remains moist or wet for short but significant periods of the growing season; consists of submesic to subhygric classes
hydric	soil wet for most or all of the growing season; watertable at or near the soil surface; consists of hygric to hydric classes

* From RAB, 1980.

13. SOIL TAXONOMY*

Symbol	Description
O.EB	Orthic Eutric Brunisol
E.EB	Eluviated Eutric Brunisol
O.SB	Orthic Sombric Brunisol
O.DYB	Orthic Dystric Brunisol
GL.DYB	Gleyed Dystric Brunisol
O.DB	Orthic Dark Brown
O.BL	Orthic Black
O.HG	Orthic Humic Gleysol
O.G	Orthic Gleysol
O.GL	Orthic Gray Luvisol
BR.GL	Brunisolic Gray Luvisol
O.HFP	Orthic Humo-Ferric Podzol
SM.HFP	Sombric Humo-Ferric Podzol
GL.HFP	Gleyed Humo-Ferric Podzol
GLSM.HFP	Gleyed Sombric Humo-Ferric Podzol
O.R	Orthic Regosol
GL.R	Gleyed Regosol

Because of variations in texture and soil wetness, some soils have been designated a dominant and subdominant (in brackets) soil development.

* From CSSC, 1978.

14. SOURCES OF FURTHER INFORMATION

CSSC, Canada Soil Survey Committee, Subcommittee on Soil Classification. 1978. The Canadian System of Soil Classification. Canada Department of Agriculture Publication 1646. Supply and Services, Ottawa, Ontario. 164 pp.

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Green, A. J. and T. M. Lord. 1979. Soils of the Princeton Area of British Columbia. Report No. 14. British Columbia Soil Survey. Agriculture Canada, Research Branch. 134 pp.

Holland, S. S. 1976. Landforms of British Columbia. A Physiographic Outline. Bulletin No. 48. British Columbia Department of Mines and Petroleum Resources. 137 pp.

Mitchell, W. R. and R. E. Green. 1981. Identification and Interpretation of Ecosystems of the Western Kamloops Forest Region. Land Management Handbook No. 2. Volumes I and II. Province of British Columbia, Ministry of Forests.

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Rice, H. M. A. 1960. Geology and Mineral Deposits of the Princeton Map-Area, British Columbia. Memoir 243. Geological Survey of Canada, Department of Mines and Technical Surveys, Canada. 136 pp.

Ryder, J. M. 1983. Terrain Inventory for the Stikine-Iskut Area, (104F, 104G and Parts of 104B and 104H). Ministry of Environment, Surveys and Resource Mapping Branch,Terrestrial Studies Section, Victoria, 83 pp.

MAP AVAILABLE FROM: MAPS-B.C., Surveys and Resource Mapping Branch, Ministry of Environment, Parliament Buildings, Victoria, British Columbia, V8V 1X4.

15. CREDITS

Mapping conducted by:	R. C. Kowall, Terrestrial Studies Section, Surveys and Resource Mapping Branch, Ministry of Environment, Kelowna, British Columbia.
Date of mapping:	June, 1983
Photography used for mapping:	Date: 1980 Scale: 1:50 000
Mapping drafted by:	Surveys and Resource Mapping Branch, Kelowna, British Columbia, 1983.
Base map provided by:	Surveys and Resource Mapping Branch, Ministry of Environment, Victoria, British Columbia.

Appendix B.3.2

Characteristics of Bonnevier and Pitin Soils
(Surveys and Resource Mapping, Ministry of Environment)

CAPAMP INPUT - SOIL CARTOGRAPHIC FILE

MAP SHEET NO. 82E

TRANS. ID.	SOIL KEY: Project	Name	AS	P1	P2	COPY KEY: Project	Name	AS	P1	P2	DUMMY VARIABLES: 1(1)	2(1)	3(1)	4(1)	7	5,6
A.D.P.C	P.E.N.T.I.C	B.V.														

FULL SOIL NAME	TAXONOMY DOMINANT	yr.	TAXONOMY SUBDOMINANT	yr.	FOREST REGION	FOREST SECTION	FOREST ZONE	BGC	FOREST SUBZONE
BONNEVIER	O.S.B	78					A.T.		D.

TRANS. ID.	DRAIN. D	DRAIN. U	PERV. D	PERV. U	STONINESS M	STONINESS S	DEPTH OF LFH M	DEPTH OF LFH S	DEPTH OF Ah OR EQUIVALENT M	DEPTH OF Ah OR EQUIVALENT S	DEPTH OF SOLUM M	DEPTH OF SOLUM S	DEPTH TO ROOT REST. LAYER M	DEPTH TO ROOT REST. LAYER S	DEPTH TO WATER TABLE M	DEPTH TO WATER TABLE S	DEPTH TO PERMAFROST M	DEPTH TO PERMAFROST S	DEPTH TO BEDROCK M	DEPTH TO BEDROCK S	TEMP. CLASS D	TEMP. CLASS U	MOIST SUBCL. D	MOIST SUBCL. U
A.D.P.D	W	M			25	5	0		32	3	41	3	-2						300	75	B			

DEPTH CD	COPY KEY	THICKNESS M	THICKNESS S	H. MAT.	PARENT MATERIAL D	PARENT MATERIAL U	COARSE FRAGMENTS M	COARSE FRAGMENTS S	TEXTURE CSSC	SAND CSSC M	SAND CSSC S	CLAY CSSC M	CLAY CSSC S	UNIFIED TEXTURE D	UNIFIED TEXTURE U	AWSC M	AWSC S	BULK DENSITY M	BULK DENSITY S	pH-$CaCl_2$ M	pH-$CaCl_2$ S	ORGANIC CARBON M	ORGANIC CARBON S	TOTAL NITROGEN M	TOTAL NITROGEN S	CEC M	CEC S	BASE SATURATION M	BASE SATURATION S	PYROPHOS Fe+Al M	PYROPHOS Fe+Al S	$CaCO_3$ M	$CaCO_3$ S	ELECTRICAL CONDUCT. M	ELECTRICAL CONDUCT. S	D.V. 3 1,2
Ah 1		1A	2	A	C		50	10	SL	60	3	4	1	SM	GM	15	2	1:52	0:08	4:50	0:2	8:5	0:9	0:380	1:1	27	4	22	3							
Bm 2		1B	3	B	C		50	10	SL	64	3	2	1	SM	GM	13	2	1:75	0:08	4:6	0:2	1:7	0:3	0:110	0:02	1A	2	17	3	0:46	0:05					
BC 3		1B	3	B	C		70	5	SL	65	2	1	1	SM	GP	6	1	2:11	0:05	4:80	0:2	1B	0:2	0:080	0:02	17	2	29	3							
C 4		60	0	C	C		70	5	SL	70	2	1	1	SM	GP	5	1	2:18	0:05	5:0	0:2	0:8	0:2	0:06	0:01	13	2	24	3							

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Figure B.3.2 CAPAMPINPUT - SOIL CARTOGRAPHIC FILE

CAPAMP INPUT - SOIL CARTOGRAPHIC FILE

MAP SHEET NO. 82E

TRANS. ID.	SOIL KEY: Project	Name	AS	P1	P2	COPY KEY: Project	Name	AS	P1	P2	DUMMY VARIABLES: 1(I)	2(I)	3(I)	4(I)	7: 5	6
A.D.P.C	PEN.T	C P.T.														

FULL SOIL NAME	TAXONOMY DOMINANT	yr.	TAXONOMY SUBDOMINANT	yr.	FOREST REGION	FOREST SECTION	FOREST ZONE BGC	FOREST SUBZONE
P.I.T.N	S.M.H.F.P	7.8	O.H.F.P	7.8			ESSF	D

TRANS. ID.	DRAIN. D	DRAIN. U	PERV. D	PERV. U	STONINESS M	STONINESS S	DEPTH OF LFH M	DEPTH OF LFH S	DEPTH OF Ah OR EQUIVALENT M	DEPTH OF Ah OR EQUIVALENT S	DEPTH OF SOLUM M	DEPTH OF SOLUM S	DEPTH TO ROOT REST. LAYER M	DEPTH TO ROOT REST. LAYER S	DEPTH TO WATER TABLE M	DEPTH TO WATER TABLE S	DEPTH TO PERMAFROST M	DEPTH TO PERMAFROST S	DEPTH TO BEDROCK M	DEPTH TO BEDROCK S	TEMP. CLASS D	TEMP. CLASS U	MOIST SUBCL.
A.D.P.D	1	M			20	5	.0		20	1	59	2	-2						300	75	6		

DEPTH CD	COPY KEY	THICKNESS M	THICKNESS S	SAT.	PARENT MATERIAL D	PARENT MATERIAL U	COARSE FRAGMENTS M	COARSE FRAGMENTS S	TEXTURE CSSC	SAND CSSC M	SAND CSSC S	CLAY CSSC M	CLAY CSSC S	UNIFIED TEXTURE D	UNIFIED TEXTURE U	AWSC M	AWSC S	BULK DENSITY M	BULK DENSITY S	pH-$CaCl_2$ M	pH-$CaCl_2$ S	ORGANIC CARBON M	ORGANIC CARBON S	TOTAL NITROGEN M	TOTAL NITROGEN S	CEC M	CEC S	BASE SATURATION M	BASE SATURATION S	PYROPHOS Fe+Al M	PYROPHOS Fe+Al S	$CaCO_3$ M	$CaCO_3$ S	ELECTRICAL CONDUCT. M	ELECTRICAL CONDUCT. S	O.V. 3	1	2
Ahu 1		1.0	2	A	C.		50	10	S.L.	59	2	7.1	2	S	M	G	M	1.6	.2	5.6	0:0.8	4:6	0:2	.75	0:4	0:4.0	0:0.9	.25	.3	32	5								
Ah 2		1.0	1	A	C.		50	10	S.L.	57	3	9	2	S	M	G	M	1.6	.2	6.3	0:0.8	4:6	0:2	5.0	0:4	0:2.8	0:0.6	1.7	.3	19	3								
Bf 3		2.0	2	B	C.		50	10	S.L.	57	3	7	1	S	M	G	M	1.1	.2	7.3	0:0.8	4:8	0:2	3.4	0:3	0:2.0	0:0.5	1.4	.2	10	2	4.1	0.9						
Bfc 4		1.2	2	B	C.		50	10	S.L.	67	3	6	1	S	M	G	M	.8	.1	9.1	0:0.8	4:8	0:2	0.9	0:2	0:1.3	0:0.2	1.1	.2	1.0	2	0.9	0.6						
Bc 5		1.5	2	B	C.		70	5	S.L.	61	3	12	2	G	M	G	P	5	.1	22.1	0:0.5	5:0	0:2	0.4	0:1	0:0.6	0:0.1	.7	.2	1.7	3								
C 6		6.0	0	C	C.		70	5	S.L.	56	2	10	2	G	M	G	P	5	.1	22.3	0:0.5	4:8	0:2	0.2	0:1	0:0.2	0:0.1	.8	.2	2.4	4								

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Figure B.3.2 (continued) CAPAMP INPUT - SOIL CARTOGRAPHIC FILE

APPENDIX C
Vegetation

Appendix C.1.1
List of Species

This list represents the species that have been recorded for the plots measured for this experiment. In addition a number of species which occurred in the immediate vicinity of the study area were collected and identified. These have been included in this list. No attempt was made to make a complete botanical record of the area.

The nomenclature follows that of Taylor and McBride (1977)[1] for vascular plants, Crum et al.(1973)[2] for mosses, Hale and Culberson (1970)[3] for lichens and Stotler and Crandall-Stotler (1977)[4] for liverworts and hornworts.

Voucher specimen are submitted with this report.

Conifers

Abies lasiocarpa (W.J. Hooker) Nuttall	alpine fir
Juniperus scopulorum Sargent	Rocky Mountain juniper
Larix Lyallii Parlatore	alpine larch
Picea Engelmannii C.C. Parry ex Engelmann	Engelmann spruce
Pinus albicaulis Engelmann	white bark pine

Broadleaf Shrubs

Arctostaphylos uva-ursi (L.) Spreng.	kinnikinnick
Potentilla fruticosa L.	shrubby cinquefoil
Salix cascadensis Cockerell	Cascade willow

Broadleaf herbs

Achillea millefolium	yarrow
Agoseris glauca (Pursh) Raf var. *dasycephala*	short-beaked false dandelion
Anemone Drummondii Wats. var. *Drummondii*	Drummond's anemone
Antennaria species J. Gaertner	pussytoes
Antennaria alpina (L.) J. Gaertner	alpine pussytoes
Antennaria lanata (W.J. Hook) Greene	woolly pussytoes
Antennaria parvifolia (Nuttall	Nuttall's pussytoes
Arenaria L.	sandwort
Arenaria capillaris Poiret	thread-leaved sandwort

Arnica mollis W.J. Hooker	hairy arnica
Castilleja Elmeri Fernald	Elmer's indian paintbrush
Cerastium Beeringianum Cham. & Schlecht	Bering chickweed
Cerastium fontanum Baumg. Subsp. triviale (Link) Jalas	common chickweed
Draba L.	whitlow-grass
Draba oligosperma	few-seeded whitlow-grass
Erigeron aureus Greene	golden fleabane
Fragaria virginiana Duch. subsp *glauca* (S. Wats.) Staudt	blue-leaved wild strawberry
Gentianella amarella (L.) Borner	northern gentian
Hieracium gracile W.J. Hooker	slender hawkweed
Lupinus L.	lupine
Lupinus arcticus S. Watson	arctic lupine
Lupinus Lyallii A. Gray	dwarf mountain lupine
Minuartia Rossii (R. Brown) Graebner	Ross' sandwort
Minuartia tenella (Nutt.) Mattfeld	slender sandwort
Oxytropis campestris (L.) A.P. deCandolle	field locoweed
Penstemon procerus D. Dougl. ex Grahams	slender blue penstemon
Phlox diffusa Bentham	spreading phlox
Polemonium pulcherrimum W.J. Hooker	showy Jacob's-ladder
Potentilla diversifolium Lehmann	blue-leaved cinquefoil
Sedum lanceolatum Torrey	lance-leaved stonecrop
Selaginella densa Rydberg	common selaginella
Senecio lugens J. Richardson	black-tipped ragwort
Sibbaldia procumbens L.	creeping sibbaldia
Silene acaulis (L.) N.J. Jacquin	moss campion
Silene parryi (S. Wats.) Hitchcock and Maquire	Parry's campion
Solidago spathulata A.P. de Candolle	spike-like goldenrod
Stellaria longipes Goldie	long-stalked starwort
Trollius laxus Salisbury	white globeflower
Veronica Cusickii A. Gray	Cusick's speedwell

Graminoid Plants

Graminaea and Juncaceae

Agropyron violaceum (Horneman) Lange	broad-glumed wheat grass
Calamagrostis purpurascens R. Brown	purple small reed grass
Danthonia californica Bolander	California oat grass
Festuca brachyphylla J.A. Schultes	alpine fescue
Hordeum jubatum L.	foxtail barley
Juncus Drummondii E.H.F. Meyer	Drummond's rush
Luzula spicata (L.) A.P. de Candolle	spiked-wood-rush
Melica L.	melic grass
Poa alpina L.	alpine bluegrass
Poa arctica R. Brown	arctic blue grass
Poa Cusickii Vasey	Cusick's blue grass
Poa Fendlariana (Steud.) Vasey	mutton grass
Trisetum spicatum (L.) K. Richter	spike trisetum

Cyperaceae

Carex L.	sedge
Carex nigricans C.A. Meyer	black alpine sedge
Carex Phaeocephala Piper	dunhead sedge
carex scirpoidea A. Micheaux	northern single-spiked sedge
Kobresia myosurioides (Villars) Fiori & Paoletti	Bellard's kobresia

Bryophytes

Musci

Dicranum fuscescens Turn.	dicranum moss
Polytrichum juniperinum Hedw.	hairy-cap moss
Polytrichum piliferum Hedw	polytrichum moss

Lichens - fruticose

Certraria cucullata (Bell) Ach.	yellow cetraria
Cetraria islandica (L.) Ach.	Iceland moss

Lichens - fruticose (coninued)

Cladina alpestris (L.) Harm	alpine cladonia
Cladonia (incl. *chlorophaea* (Florke ex Somm.) Spreng. and *pleurota* (Florke) Schaer.)	cup-shaped lichens
Cladonia cornuta (L.) Hoffm. and *Thamnolia subuliformis* (Ehrh.) Culb.	antler-shaped lichens
Usnea hirta (L.) Wigg.	spanish moss

Lichens - Crustose/squamulose

mainly epilithic lichens forming black, grey or yellow crusts or squamules on rock surfaces.

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2 Crum H.A., W.C. Steere, and L.E. Anderson, 1973. A New List of Mosses of North America North of Mexico. The Bryologist Vol. 76 (1), 1973. p. 85-130.

3 Hale M.E. Jr. and W.L. Culberson. 1970. A Fourth Checklist of the Lichens of the Continental United States and Canada. The Bryologist Vol.73 (3), 1970. p. 499-543.

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Appendix C.1.2

Table C.1.2 Species Composition of Plots of Each Transect

Transect	I						II						III						IV						FF	FF
Plot Nr.	1	2	3	4	5	CONST	1	2	3	4	5	CONST	1	2	3	4	5	CONST	1	2	3	4	5	CONST	1	2
Conifer																										
Juniperus scopulorum																										
Broad leaf Shrubs																										
Arctostaphylos uva-ursi																										
Potentilla fruticosa											✓	1							✓	✓				2		
Salix Cascadensis																										
Broad-leaf Herbs																										
Achillea millefolium				✓		1		✓		✓		2			✓			1			✓	✓		2		
Agoseris glauca																					✓	✓		2		
Anemone drummondii																					✓	✓	✓	3		
Antennaria species																	✓	1	✓					1		
alpina	✓	✓			✓	3	✓	✓	✓	✓		4	✓			✓		2		✓	✓	✓	✓	4	✓	✓
lanata																										
Arenaria species																										
capillaris									✓	✓		2	✓			✓		2								
Carastium Beeringianum			✓			1									✓			1								
Draba species															✓			1								
oligosperma										✓		1									✓			1		
Erigeron aureus																							✓	1		
Gentianella amarella	✓	✓	✓	✓	✓	5	✓		✓	✓	✓	4	✓	✓		✓		3		✓	✓	✓	✓	4		
Lupinus species																										
arcticus		✓	✓			2							✓					1								
Lyallii																			✓					1	✓	
Minuartia rossii				✓	✓	2		✓		✓	✓	3	✓	✓	✓	✓	✓	5	✓		✓		✓	3	✓	✓
tenella														✓				1								
Oxytropis campestris							✓		✓			2	✓		✓	✓		3		✓	✓	✓	✓	4		
Pensteron procerus			✓	✓		2																				
Polemonium pulcherrimum		✓				1					✓	1								✓		✓	✓	3		
Potentilla diversifolium	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓
Sedum lanceolatum			✓	✓	✓	3	✓						✓				✓	2								
Selaginella densa	✓	✓	✓	✓	✓	5		✓	✓	✓		3	✓		✓	✓	✓	4			✓	✓	✓	3	✓	✓
Sibbaldia procumbens																										
Silene acaulis																										
Solidago spathulata	✓	✓		✓		3		✓	✓	✓	✓	4			✓	✓	✓	3	✓		✓			2	✓	✓
Stellaria longipes																			✓	✓	✓	✓		4		
Unidentified			✓			1																				
Graminoid Herbs: Grasses and Rushes																										
Agropyron violaceum																				✓		✓	✓	3		
Danthonia California	✓		✓	✓	✓	4		✓	✓	✓	✓	4	✓			✓		2		✓		✓	✓	3		
Festuca brachyphylla	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓
Luzula spicata																			✓					1		
Poa alpina													✓					1					✓	1	✓	
Trisetum spicatum	✓		✓			2	✓				✓	2								✓	✓			2		
Graminoid Herbs: Cyperaceae																										
Carex species																					✓			1	✓	✓
nigricans																			✓	✓		✓		3		
scirpoidea	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5					✓	1		
Kobresia myosuroides																✓		1								
Bryophytes: Musci																										
Polytrichum (juniperinum and piliferum)	✓	✓	✓		✓	4		✓	✓		✓	3	✓			✓	✓	3	✓	✓	✓	✓	✓	5	✓	✓
Lichens-fruticose																										
Cetraria cucullata	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓
Islandica	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5		✓	✓			2	✓	✓	✓	✓	✓	5		✓
Cladina alpestris	✓					1					✓	1														
Cladonia (chlorophaea and pleurota)			✓			1				✓		1														
Cladonia cornuta and Thamnolia subuliformis	✓				✓	2				✓		1								✓		✓		2		
Usnea hirta																✓		1								
Lichen - Crustose/squamulose			✓		✓	2		✓	✓	✓		3	✓	✓	✓			3	✓	✓	✓	✓	✓	5		
Boulder		✓			✓	2				✓		1		✓	✓			2								
Date	June 1, 1984						June 1, 1984						June 1, 1984						Sept. 7, 1984						Aug. 15, 1984	Aug. 15, 1984
Comments	I-5 hummocky, Sal. densa and lichen on hummocks. Boulders covered with black lichen I-3 more evenly vegetated I-2 very rocky I-1 frost boil in ne corner						II-1 lightly vegetated, some stone striping II-2 light grassy cover II-3 moderate grass cover II-4 heavily grassed, few bryophytes II-5 well vegetated						III-5 very poorly vegetated III-1 small frost boil						Wind exposed convex south slope from 5-15%						Covered with erosion cloth after removal platform and cave shelter	Vegetation dead or inactive. Solidago stems white and purple, damaged.

Table C.1.2 (continued)
Species Composition of Plots of Each Transect-Continued

Transect	V						VI						SPF		SPF		ST		ST		TOTAL	
Plot No	1	2	3	4	5	TOTAL	1	2	3	4	5	TOTAL	2A	2B	1A	1B	1A	1B	2A	2B	A	A+B
Conifer																					N=4	N=8
Juniperus scopulorum																						
Broad leaf Shrubs																						
Arctostaphylos uva-ursi		✓				1		✓				1										
Potentilla fruticosa		✓		✓		2																
Salix Cascadensis																						
Broad-leaf Herbs																						
Achillea millefolium	✓			✓		2	✓					1										
Agoseris glauca																						
Anemone drummondii									✓		✓	2										
Antennaria species																						
alpina					✓	1	✓		✓	✓	✓	4			✓		✓	✓	✓	✓	4	5
lanata																						
Arenaria species																						
capillaris			✓			1							✓									1
Cerastium Beeringianum								✓				1										
Draba species																						
oligosperma																						
Erigeron aureus													✓	✓		✓					1	3
Gentianella amarella	✓	✓		✓		3	✓		✓	✓	✓	4					✓				1	1
Lupinus species																						
arcticus																						
Lyallii																						
Minuartia rossii	✓	✓	✓			3	✓	✓	✓	✓	✓	5	✓		✓	✓	✓	✓	✓	✓	4	7
tenella																						
Oxytropis campestris	✓		✓	✓	✓	4	✓		✓		✓	3										
Penstemon procerus										✓	✓	2										
Phlose diffusa	✓		✓	✓		3	✓	✓	✓	✓	✓	5	✓		✓		✓	✓	✓	✓	4	7
Polemonium pulcherrimum			✓			1	✓		✓			2	✓	✓	✓		✓	✓		✓	3	6
Potentilla diversifolium	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	✓	✓	✓	4	8
Sedum lanceolatum													✓							✓	1	2
Selaginella densa	✓	✓		✓	✓	4	✓	✓		✓	✓	4	✓	✓	✓	✓	✓	✓	✓	✓	4	8
Sibbaldia procumbens									✓			1	✓	✓			✓				2	3
Silene acaulis																	✓	✓			1	2
Solidago spathulata	✓		✓	✓		3	✓	✓	✓			3			✓	✓	✓	✓	✓	✓	3	6
Stellaria longipes																			✓		1	1
Unidentified																				✓		1
Graminoid Herbs: Grasses and Rushes																						
Agropyron violaceum																						
Danthonia Californica	✓	✓	✓			3	✓	✓	✓		✓	4	✓								1	1
Festuca brachyphylla	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	✓	✓	✓	4	8
Luzula spicata								✓				1										
Poa alpina					✓	1											✓	✓	✓	✓	2	4
Trisetum spicatum	✓				✓	2		✓			✓	2					✓	✓	✓	✓	2	4
Graminoid: Herbs: Cyperaceae																						
Carex species													✓		✓		✓	✓	✓		4	5
nigricans	✓	✓	✓		✓	4	✓		✓			2				✓				✓		2
scirpoidea	✓			✓		2	✓	✓		✓	✓	4										
Kobresia myosuroides																						
Bryophytes: Musci																						
Polytrichum (juniperinum and piliferum)	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓	5	✓	✓	✓	✓	✓		✓	✓	4	7
Lichens-fruticose																						
Cetraria cucullata			✓	✓	✓	3	✓	✓	✓	✓		4					✓	✓	✓	✓	2	4
Islandica	✓			✓	✓	3	✓	✓	✓		✓	4			✓	✓		✓	✓	✓	2	5
Cladina alpestris																						
Cladonia (chlorophaea and pleurota)							✓	✓			✓	3	✓		✓	✓				✓	2	4
Cladonia cornuta and Thamnolia subuliformis									✓		✓	2			✓					✓	1	2
Usnea hirta					✓	1																
Lichen - Crustose/squamulose																				✓		1
Peltigera species													✓								1	1
Date of Records	September 6, 1984						September 6, 1984						September 6, 1984									
Comments							V1-4 Juniper scopulorum near plot						2b- covered with erosion cloth		1b- uncovered		1A- recorded in Sept., 1984 1B- recorded in June 1984		2A recorded in Sept. 1984 2B recorded in June 1984			

Table C.1.2 (continued)
Species Composition of Plots of Each Transect

Transect	R				TOTAL
Plot Nr.	1	2	1C	2C	
Conifer					
Juniperus scopulorum					
Broad leaf Shrubs					
Arctostaphylos uva-ursi					
Potentilla fruticosa					
Salix Cascadensis					
Broad-leaf Herbs					
Achillea millefolium	✓	✓	✓		3
Agoseris glauca					
Anemona drummondii					
Antennaria species					
alpina	✓	✓	✓	✓	4
lanata					
Arenaria species					
capillaris					
Cerastium Beeringianum					
Draba species					
oligosperma					
Erigeron aureus					
Gentianella amarella			✓	✓	2
Lupinus species					
arcticus	✓	✓	✓	✓	4
Lyallii					
Minuartia rossii	✓	✓	✓	✓	4
tenella					
Oxytropis campestris		✓			1
Penstemon procerus					
Polemonium pulcherrimum	✓	✓	✓	✓	4
Potentilla diversifolium	✓	✓	✓		3
Sedum lanceolatum		✓		✓	2
Selaginella densa		✓	✓	✓	3
Sibbaldia procumbens					
Silene acaulis					
Solidago spathulata	✓	✓	✓	✓	4
Stellaria longipes					
Unidentified	✓			✓	2

Table C.1.2
Species Composition of Plots of Each Transect (Continued)

Transect	R				TOTAL
Plot Nr.	1	2	1C	2C	
Graminoid Herbs: Grasses and Rushes					
Agropyron violaceum					
Danthonia Californica					
Festuca brachyphylla	✓	✓	✓	✓	4
Luzula spicata		✓			1
Poa alpina	✓	✓	✓	✓	4
Trisetum spicatum	✓			✓	2
Graminoid Herbs: Cyperaceae					
Carex species					
nigricans	✓	✓	✓	✓	4
scirpoidea					
Kobresia myosuroides					
Bryophytes:					
Musci					
Polytrichum (juniperinum and piliferum)	✓	✓		✓	3
Lichens-fruticose					
Cetraria cucullata	✓	✓	✓	✓	4
Islandica	✓	✓	✓	✓	4
Cladina alpestris					
Cladonia (chlorophaea and pleurota)					
Cladonia cornuta and Thamnolia subuliformis	✓	✓	✓		3
Usnea hirta					
Lichen - Crustose/squamulose					
Peltigera species		✓	✓	✓	3
Date	June 1, 1984				
Comments	Somewhat wetter due to snowmelt				

Table C.1.3

Species Composition and Frequencies for Transects and Plotgroups of the Study Area

Transect (No of Plots)	I (5)	II (5)	III (5)	IV (5)	V (5)	VI (5)	SPF (2)	PF (2)	ST (4)	R (4)	TOTAL (44)	CONSTANCY %
Conifer												
Juniperus scopulorum												
Broad leaf Shrubs												
Arctostaphylos uva-ursi					1	1					2	4.5
Potentilla fruticosa		1		2	2						5	11.4
Salix Cascadensis												
Broad-leaf Herbs												
Achillea millefolium	1	2	1	2	2	1				3	12	27
Agoseris glauca				2							2	4.5
Anemona drummondii				3		2					5	11.4
Antennaria species	1										1	2.3
alpina	3	4	2	4	1	4	1	2	2	4	27	61.4
lanata												
Arenaria species												
capillaris		2	2		1						5	11.4
Cerastium Beeringianum	1		1			1					3	6.8
Draba species			1								1	2.3
oligosperma		1		1							2	4.5
Erigeron aureus				1			1				2	4.5
Gentianella amarella	5	4	3	4	3	4			1	2	26	59.1
Lupinus species												
arcticus	2		1							4	7	15.9
Lyallii				1				1			2	4.5
Minuartia rossii	2	3	5	3	3	5	2	2	2	4	31	70.5
tenella			1								1	2.3
Oxytropis campestris		2	3	4	4	3				1	17	38.6
Penstemon procerus	2					2					4	9.1
Polemonium pulcherrimum	1	1		3		2	2		1	4	14	31.8
Potentilla diversifolium	5	5	5	5	5	5	2	2	2	3	39	88.4
Sedum lanceolatum	3		2				1			2	8	18.2
Selaginella densa	5	3	4	3	4	4	2	2	2	3	32	72.7
Sibbaldia procumbens						1	1	1			3	6.8
Silene acaulis									1		1	2.3
Solidago spathulata	3	4	3	2	3	3	1	2	2	4	27	61.4
Stellaria longipes				4					1		5	11.4
Unidentified	1									2	3	6.8
Graminoid Herbs: Grasses and Rushes												
Agropyron violaceum				3							3	6.8
Danthonia Californica	4	4	2	3	3	4	1				21	48.0
Festuca brachyphylla	5	5	5	5	5	5	2	2	2	4	40	90.9
Luzula spicata				1		1				1	3	6.8
Poa alpina					1			1	2	4	8	18.2
Trisetum spicatum	2	2	1	2	2	2			2	2	15	34.1
Graminoid Herbs: Cyperaceae												
Carex species				1			2	2	2		7	16
nigricans				3	4	2				4	13	29.5
scirpoidea	5	5	5	1	2	4					22	50
Kobresia myosuroides			1								1	2.3
Bryophytes: Musci												
Polytrichum (juniperinum and piliferum)	4	3	3	5	5	5	2	2	2	3	34	77.3
Lichens-fruticose												
Cetraria cucullata	5	5	5	5	3	4		2	2	4	35	79.5
Islandica	5	5	2	5	3	4	1	1	1	4	31	70.5
Cladina alpestris	1	1									2	4.5
Cladonia (chlorophaea and pleurota)	1	1				3	2	1			8	18
Cladonia cornuta and Thamnolia subuliformis	2	1		2		2	1			3	11	25
Usnea hirta			1		1		1				1	2.3
											2	4.5
Lichen - Crustose/squamulose	2	3	3	5						3	16	36.4
Peltigera species							1				1	2.3

Appendix C.2 Percent Crowncover of Vegetation Before and After Filming

Table C.2 PERCENT CROWNCOVER OF VEGETATION BEFORE AND AFTER FILMING

OBS	I	VEG1	VEG2	VEG3	VEG4	VEG5	VEG6	VEG7*	VEG8	VEG9	VEG10	VEG11	VEG12	VEG13	VEG14	TRAN	PLOTNO	INTERP	TIME
1	15	0	0	10	33	76	43	86	7	1	6	0	6	6	1	1	1	T	B
2	15	0	0	10	25	77	52	87	8	2	6	0	3	3	2	1	1	T	A
3	15	0	0	30	63	63	0	93	2	2	0	0	3	3	1	1	2	T	B
4	15	0	0	15	16	78	62	93	0	0	0	0	5	5	2	1	2	T	A
5	15	0	0	13	21	69	48	82	6	6	0	0	6	6	6	1	3	T	B
6	15	0	0	3	20	20	2	23	11	11	6	6	58	64	0	1	3	T	D
7	15	0	0	15	30	54	24	69	21	0	33	2	4	6	4	1	4	T	B
8	15	0	0	24	9	51	42	75	9	0	25	13	2	15	1	1	4	T	D
9	15	0	0	12	32	73	41	85	1	1	0	0	6	6	8	1	5	T	B
10	15	0	0	11	10	78	68	89	0	0	3	2	6	8	3	1	5	T	D
11	15	0	0	19	60	60	1	79	15	15	4	4	0	4	1	2	1	B	B
12	15	0	0	22	58	58	3	80	14	14	2	2	0	2	1	2	1	B	A
13	15	0	0	9	81	81	0	90	3	3	6	6	0	6	1	2	2	B	A
14	15	0	0	11	77	77	0	88	1	1	13	13	7	20	1	2	2	B	A
15	15	0	0	11	64	64	0	75	9	9	14	14	0	14	2	2	3	B	B
16	15	0	0	13	61	61	0	74	5	5	13	13	7	20	1	2	3	B	B
17	15	0	0	25	45	45	2	70	26	26	1	1	0	1	1	2	4	B	B
18	15	0	0	13	10	10	4	23	1	1	19	19	53	72	0	2	4	B	D
19	15	0	0	34	34	34	2	68	27	27	2	2	0	2	1	2	5	B	B
20	15	0	0	29	25	25	4	54	2	2	7	7	33	40	0	2	5	B	D
21	15	0	0	28	10	55	45	83	0	0	2	1	6	7	10	3	1	T	B
22	15	0	0	10	34	38	4	48	38	38	0	1	12	13	1	3	1	T	A
23	15	0	0	14	4	54	50	68	26	3	23	0	2	2	1	3	2	T	B
24	15	0	0	5	10	70	60	75	17	0	20	1	3	4	5	3	2	T	B
25	15	0	0	38	1	40	39	78	17	8	9	0	4	4	1	3	3	T	B
26	15	0	0	11	2	66	64	77	17	0	20	1	3	4	2	3	3	T	D
27	15	0	0	23	5	55	50	78	5	0	5	0	5	5	12	3	4	T	B
28	15	0	0	20	9	70	61	90	7	2	5	0	2	2	1	3	4	T	B
29	15	0	0	27	1	32	31	59	20	3	17	0	3	3	18	3	5	T	A
30	15	0	0	13	2	60	58	73	20	2	18	0	2	2	5	3	5	T	D
31	15	0	0	26	20	49	29	75	18	12	6	1	4	5	2	4	1	T	B
32	15	0	0	20	9	51	42	71	24	17	7	1	2	3	2	4	1	T	B
33	15	0	0	20	28	59	31	79	17	16	1	0	3	3	1	4	2	T	B
34	15	0	0	24	15	54	39	78	19	18	1	0	2	2	1	4	2	T	A
35	15	0	0	29	24	56	32	85	0	0	0	0	4	4	11	4	3	T	B
36	15	0	0	28	24	57	33	85	2	2	0	0	5	5	8	4	3	T	B
37	15	0	0	14	24	69	45	83	6	0	6	0	3	3	8	4	4	T	A
38	15	0	0	8	30	77	47	85	4	0	7	0	4	4	7	4	4	T	A
39	15	0	0	30	31	63	32	93	2	0	3	0	3	3	2	4	5	T	B
40	15	0	0	20	24	75	51	95	3	0	3	0	1	1	1	4	5	T	A
41	15	0	0	26	19	56	37	82	15	0	16	0	1	1	2	5	1	T	B
42	15	0	0	20	9	64	55	84	13	0	15	2	1	3	0	5	1	T	D
43	15	0	0	23	27	67	40	90	0	0	0	0	5	5	5	5	2	T	B
44	15	0	0	9	16	85	69	94	0	0	3	2	1	3	3	5	2	T	B
45	15	0	0	6	42	82	40	88	7	0	13	1	2	3	2	5	3	T	B
46	15	0	0	4	24	79	55	83	7	0	17	7	1	8	2	5	3	T	A
47	15	0	0	17	28	71	43	88	6	1	5	0	4	4	2	5	4	T	B
48	15	0	0	9	15	79	64	88	4	0	9	4	2	6	2	5	4	T	A
49	15	0	0	9	43	86	43	95	0	0	0	0	4	4	1	5	5	T	A
50	15	0	0	5	22	91	69	96	0	0	0	0	1	1	1	5	5	T	A
51	15	0	0	17	24	70	46	87	8	2	6	0	3	3	2	6	1	T	B
52	15	0	0	15	22	74	52	89	3	0	5	2	2	4	4	6	1	T	A
53	15	0	0	20	10	65	55	85	7	0	10	1	4	5	3	6	2	T	A
54	15	0	0	15	19	66	47	81	7	0	11	4	4	8	4	6	2	T	A
55	15	0	0	15	22	53	31	68	26	0	26	1	2	3	3	6	3	T	B
56	15	0	0	10	18	59	41	69	25	0	26	2	3	5	1	6	3	T	A
57	15	0	0	9	20	72	52	81	9	0	12	2	5	7	3	6	4	T	B
58	15	0	0	11	24	72	48	83	12	0	13	1	1	2	3	6	4	T	A
59	15	0	0	12	22	72	50	84	8	0	10	1	6	7	1	6	5	T	B
60	15	0	0	8	18	76	58	84	9	0	10	1	4	5	2	6	5	T	A

* For Samples with Interp = T this includes dead graminoid materials

Table C.2 (continued)

Legend

OBS	=	Observation number generated by program
I	=	Computer generated counter
VEG1	=	Broadleaved Trees
VEG2	=	Coniferous Trees
VEG3	=	Broadleaved Herbs and Low Shrubs
VEG4	=	Living Graminoid Foliage for Interp = T, or Total Graminoid Foliage for Interp = B
VEG5	=	Total Graminoid Foliage
VEG6	=	Litter, including Dead Graminoid Foliage for Interp = T
VEG7	=	Total Herbaceous Cover
VEG8	=	Total Bryophyte Cover, includes epilithic bryophtes for Interp = T
VEG9	=	Bryophytes on unconsolidated soil
VEG10	=	Total exposed surface of boulders and stones (includes epilithic bryophyte surfaces)
VEG11	=	Non-Vegetated surfaces of boulders and stones (excludes epilithic bryophyte surfaces)
VEG12	=	Non-Vegetated soil surfaces, including areas of severely damaged vegetation roots)
VEG13	=	Total Unvegetated area
VEG14	=	Unknown surface cover
TRAN	=	Transect number from 1 (I) to 6 (VI)
PLOTNO	=	Plot number within TRANsect
INTERP	=	Interpreter T refers to Thompson, B refers to van Barneveld
TIME	=	Application of treatment, and observed impacts, B = before application of treatment, A = after application of treatment and no observed damage, D = after application of treatment and visibly damaged.

Table C. 3 Summary of Statistics of Transects Before Impacts, and Cover Values for Post-Filming Damage-Free and Damaged Sites

Transect	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Vegetation	Broadleaf						Graminoid (incl. Litter)						Total Herbs						Bryophytes (incl. Selaginella)					
BEFORE Statistic																								
MEAN	16	19.6	26	23.8	16.2	14.6	67	57.8	47.2	59.2	72.4	66.4	83	77.4	73.2	83	88.6	81	7.4	16	13.6	8.6	5.6	11.6
MAX	30	34	38	30	26	20	76	81	55	69	86	72	93	90	83	93	95	87	21	27	26	18	15	26
MIN	10	9	14	14	6	9	54	36	32	49	56	53	69	70	59	75	82	68	1	3	0	0	0	7
MEDIAN	13	19	27	26	17	15	69	61	54	59	71	70	85	75	78	83	88	84	6	15	17	6	6	8
RANGE	20	25	24	16	20	11	22	45	23	20	30	19	24	20	24	18	13	19	20	24	26	18	15	19
SD	8.03	10.29	8.69	6.72	8.64	4.28	8.75	17.17	10.62	7.50	12.01	8.02	8.80	7.99	9.63	6.78	4.67	7.58	8.02	10.49	10.78	8.41	6.19	8.08
VAR	64.5	105.8	75.5	45.2	74.7	18.3	76.5	294.7	112.7	56.2	144.3	64.3	77.5	63.8	92.7	46	21.80	57.5	64.3	110	116.3	70.8	38.3	65.3
N	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
AFTER 1	10	22	10	20		15	77	61	38	51		74	87	83	48	71		89	8	14	38	24		3
AFTER 2	15	11	5	24		15	78	77	70	54		66	93	88	75	75		81	0	1	17	19		7
AFTER 3		13		28	4	10		61		57	79	59		74		85	83	69		5		2	7	25
AFTER 4			20	8	6	11			70	77	79	72			90	85	85	83			7	4	4	12
AFTER 5				20	3	8				75	91	76				95	94	94				3	0	9
MEAN	12.5	15.3	11.7	20	4.3	11.8	77.5	66.3	59.7	62.8	83	69.4	90	81.7	71	82.2	87.3	83.2	4	6.67	20.7	10.4	3.7	11.2
SD				7.48		3.11				12.26		6.91				9.44		9.44				10.31		8.38
DAMAGED 1					20						64						84						13	
DAMAGED 2					9						88						97							
DAMAGED 3	3		11				22		66				25		77				11		17			
DAMAGED 4	24	13					51	14					75	27					9	1				
DAMAGED 5	11	29	13				78	29	60				89	58	73				0	2	20			
DAMAGED MEAN	13.7	21	12		14.5		50.3	21.5	63		76		63	42.5	75		90.5		7.3	1.5	18.5		6.5	
MEAN TOT.	12.6	17.6	11.8	20	8.4	11.8	61.2	48.4	60.8	62.8	80.2	69.4	73.8	66	72.6	82.2	88.6	83.2	5.6	4.6	19.8	10.4	4.8	11.2
SD	7.70	7.67	5.45	7.48	6.88	3.11	24.77	25.96	13.39	12.26	10.52	6.91	20.09	24.61	15.27	9.44	6.43	9.44	5.22	5.50	11.3	10.31	5.45	8.38
Vegetation	Unknown						Consolidated Unvegetated						Non-Vegetated Unconsolidated						Total Non-Vegetated					
BEFORE Statistic																								
MEAN	4.2	1.2	8.4	4.8	2.4	2.4	0.4	5.4	.2	.2	.2	1	5	0	4.6	3.4	3.2	4	5.4	5.4	4.8	3.6	3.4	5
MAX	8	2	18	11	5	3	2	14	1	1	1	2	6	0	6	4	5	6	6	14	7	5	5	7
MIN	1	1	1	1	1	1	0	1	0	0	0	0	3	0	3	3	1	2	3	1	3	3	1	3
MEDIAN	4	1	10	2	2	3	0	4	0	0	0	1	6	0	5	3	4	4	6	4	5	3	4	
RANGE	7	1	17	10	4	2	2	13	1	1	1	2	3	0	3	1	4	4	3	13	4	2	4	4
SD	2.86	.45	7.37	4.44	1.52	.89	.89	5.18	.45	.45	.45	.71	1.41	0	1.14	.55	1.64	1.58	1.34	5.18	1.48	.89	1.52	2
VAR	8.2	.20	54.3	19.7	2.3	.80	.8	26.8	.2	.2	.2	.50	2	0	1.3	.30	2.7	2.5	1.80	26.8	2.20	.80	2.30	4
N	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5				
AFTER 1	2	1	1	2		4	0	2	1	1		2	3	0	12	2		2	3	2	13	3		4
AFTER 2	2	1	5	1		4	0	7	1	0		4	5	3	2	2		4	5	10	3	2		8
AFTER 3		1		8	2	1		13		0	7	2		7		5	1	3		20		5	8	5
AFTER 4			1	7	2	3			0	0	4	1			2	4	2	1			2	4	6	2
AFTER 5				1	3	2				0	0	1				1	1	4				1	1	5
MEAN	2	1	2.3	3.8	2.3	2.8	0	7.3	.67	.2	3.7	2	4	33	5.3	2.8	1.3	2.8	4	10.7	6	3	5	4.8
SD		0		3.42		1.30	0			.45		1.22				1.64		1.30				1.58		2.17
DAMAGED 1					0						2						1						3	
DAMAGED 2					3						2						1						3	
DAMAGED 3	0		2				6		1				58		3				64		4			
DAMAGED 4	1	0					13	19					2	53					15	72				
DAMAGED 5	3	0	5				2	7	0				6	33	2				8	40	2			
DAMAGED MEAN	1.3	0	3.5		1.5		7	13	.5		2		22	43	2.5		1		29	56	3		3	
MEAN TOT.	1.6	.6	2.8	3.8	2	2.8	4.2	9.6	.6	.2	3	2	14.8	19.2	4.2	2.8	1.2	2.8	19	28.8	4.8	3	4.2	4.8
SD	1.14	.55	2.05	3.42	1.22		5.50	6.54	.55	.45	2.65	1.22	24.70	23.00	4.38	1.64	.45	1.30	25.56	28.02	4.66	1.58	2.77	2.17

Appendix C.4

Table C.4
Overview of Events in 1984

Structure/Feature	Events	Time Period
Cave	platform construction	1/6 - 5/6
	cave-shell placement	completed by 19/6
	heater placed in cave	4/7
	removal and clean-up	15/8-20/8
	final observations	6/9
Ramps	construction	5/7 - 23/7
	removal	7/8 - 8/8 (a few hours on 23/7)
	final observations	6/9
Staging Platforms	construction	7/6 - 19/6
	expansion to 14X15M	3/7
	removal	7/8 - 15/8
	plot location	15/8
	final observations	28/8, 6/9
Generator Platform (not originally planned)	construction	19/7
	removal	28/8
	final observation	none
Staging Area Traffic	platform construction	7/6 - 19/6
	platform removal	5/7
	returned probes	6/7
	film activity	3/7 -3/8
Foot Traffic Transects	location of plots	28/6 - 6/7
	experimental walks final observations	3/7 - 24/8
		6/9
Cave Front Scene Location	location of plots	6/6 - 7/6
	platform/cave construction	1/6 - 19/6
	filming	6/7 - 2/8
	removal of cave/platform	15/8-20/8
	final observations	6/9
Control Transect	location of plots	6/6
	final observations	6/9

Appendix C.5
Table C.5
Dates of Walks on Controlled Trampling Transects

Dates	Walks per Day		Dates	Walks per Day	
July	5	25	August	5	25
3		✓	1	✓	✓
4		✓	2	✓	✓
5		✓	3	✓	✓
6	✓	✓	7	✓	✓
9	✓	✓	9	✓	✓
10	✓	✓	10	✓	✓
11	✓	✓	13	✓	✓
12	✓	✓	14	✓	✓
13	✓	✓	15	✓	✓
16	✓	✓	17	✓	✓
17	✓	✓	20	✓	✓
18	✓	✓	21	✓	✓
19	✓	✓	22	✓	✓
20	✓	✓	23	✓	✓
23	✓	✓	24	✓	✓
24	✓	✓			
25	✓	✓			
27	✓	✓			
30	✓	✓			
31	✓	✓			
Sub Total	17	20		15	15
Total Days Walked				32	35

Appendix C.6 Characteristics of Hiker for Controlled Trampling Experiment.

Table C.6 Hiker's Characteristics

Weight of Hiker: app. 73 kg
Sole area 377.8 cm^2.
Sole Surface: Smooth
Physique: athletic, long legged
Step distance: app. 130 cm.
Probability of "hit"/step: 0.25
Maximum Pressure on Ground: 730 g/cm^2
Rest Pressure on Ground: 415 g/cm^2
Minimum Pressure on Ground: 300 g/cm^2

Additional Impacts:

1) Impact from speed of foot on landing
2) Energy from twisting motion
3) Soil elasticity

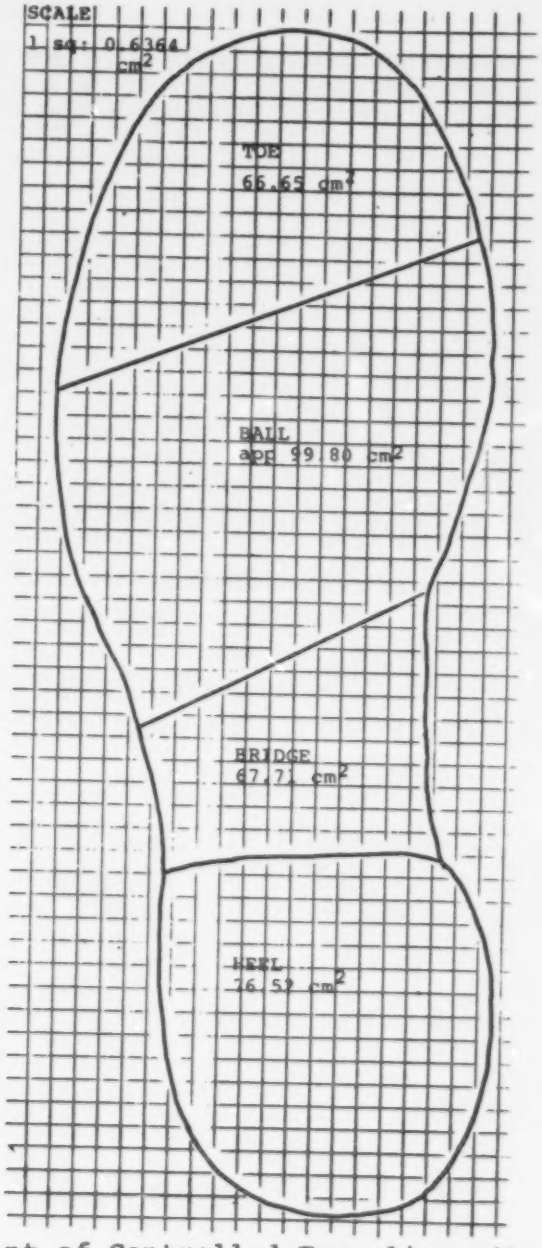


FIGURE C.6.1 Footprint of Controlled Trampling Hiker.

Appendix C.7

Table C.7 Program Listing for Data Analysis. (The example is for VEG3=Broadleaved Herb only. Lines 29, 43 and 48 are changed to get the analysis for other Vegetation Cover Categories)

```
      S A S   L O G    OS SAS 82.4          MVS/XA JOB CAVESAND STEP SAS      PROC

NOTE: THE JOB CAVESAND HAS BEEN RUN UNDER RELEASE 82.4 OF SAS AT BRITISH COLUMBIA SYSTEMS CORPORATION (0140100
NOTE: CPUID    VERSION = 44  SERIAL = 020617  MODEL = 3084 ;
      CPUID    VERSION = 44  SERIAL = 220617  MODEL = 3084 ;
NOTE: SAS OPTIONS SPECIFIED ARE:
      SORT=4

1           * CREATE TEMPORARY DATA SET CLANTEMP;
2           DATA CLANTEMP;
3           INFILE CLANSAS;
4           ARRAY VEG(I) VEG1-VEG14;
5           INPUT TRAN PLOTNO INTERP$ TIME$ VEG1-VEG14;
6           * CALCULATE ACTUAL VALUES;
7           IF INTERP='T' THEN VEG5=VEG4-VEG5;
8           IF INTERP='T' THEN VEG9=VEG8-VEG10;
9           IF INTERP='B' THEN VEG5=VEG4;
10          IF INTERP='B' THEN VEG9=VEG8;
11          IF INTERP='B' THEN VEG10=VEG11;
12          VEG13=VEG12+VEG11;
13          VEG7=VEG5+VEG3;
14          * SET NEGATIVE VALUES TO ZERO AS THESE ARE ERRORS IN ESTIMATES;
15          DO OVER VEG;
16          IF VEG<0 THEN VEG=0;
17          END;

NOTE: INFILE CLANSAS IS:
      DSNAME=SC44977.LIB.CLANSAS,
      UNIT=DISK,VOL=SER=VSR838,DISP=SHR,
      DCB=(BLKSIZE=800,LRECL=80,RECFM=FB)

NOTE: 40 LINES WERE READ FROM INFILE CLANSAS.
NOTE: DATA SET WORK.CLANTEMP HAS 40 OBSERVATIONS AND 19 VARIABLES. 300 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.12 SECONDS AND 276K.

18          PROC PRINT;
19          TITLE PERCENT CROWNCOVER OF VEGETATION BEFORE AND AFTER FILMING;
20          * SELECT ANALYSIS VARIABLES;

NOTE: THE PROCEDURE PRINT USED 0.17 SECONDS AND 276K AND PRINTED PAGES 1 TO 2.

21          DATA CLANOVA;
22          ARRAY VES(I) VEG1-VEG14;
23          SET CLANTEMP;
24          KEEP TRAN PLOTNO TIME VEG3 VEG5 VEG9 VEG11 VEG12;
25          * MAKE DATA SETS FOR ANOVA AND GLM FOR ONE OF 5 COVER TYPES;

NOTE: DATA SET WORK.CLANOVA HAS 40 OBSERVATIONS AND 8 VARIABLES. 690 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.07 SECONDS AND 276K.

26          DATA CLANVEG;
27          SET CLANOVA;
28          ARRAY VEG(I)VEG1-VEG14;
29          KEEP TRAN PLOTNO TIME VEG3;

NOTE: DATA SET WORK.CLANVEG HAS 60 OBSERVATIONS AND 4 VARIABLES. 1304 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.06 SECONDS AND 276K.

30          PROC PRINT;
31          TITLE PERCENT COVER OF VEGETATION;
32          *SORT DATA SET BY TIME AND TRANSECT;

NOTE: THE PROCEDURE PRINT USED 0.12 SECONDS AND 276K AND PRINTED PAGES 3 TO 4.

33          PROC SORT DATA=CLANVEG OUT=CLANO2WY;
34          BY TIME TRAN;
35          * CREATE DATA SET FOR BEFORE ANOVA;

NOTE: 4 CYLINDERS DYNAMICALLY ALLOCATED ON DISK FOR EACH OF 3 SORT WORK DATA SETS.
NOTE: DATA SET WORK.CLANO2WY HAS 60 OBSERVATIONS AND 4 VARIABLES. 1304 OBS/TRK.
NOTE: THE PROCEDURE SORT USED 0.40 SECONDS AND 448K.

36          DATA CLANOBEF;
37          SET CLANO2WY;
38          IF TIME='B';

NOTE: DATA SET WORK.CLANOBEF HAS 30 OBSERVATIONS AND 4 VARIABLES. 1304 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.06 SECONDS AND 276K.

39          PROC PRINT;
40          TITLE ANOVA FOR SITE;

NOTE: THE PROCEDURE PRINT USED 0.11 SECONDS AND 276K AND PRINTED PAGE 5.

41          PROC ANOVA DATA=CLANOBEF;
42          CLASS TRAN;
43          MODEL VEG3=TRAN;
44          MEANS TRAN/DUNCAN LSD;
45          * DO ANOVA FOR TIME AND TRANSECT;

NOTE: THE PROCEDURE ANOVA USED 0.17 SECONDS AND 308K AND PRINTED PAGES 6 TO 9.

46          PROC GLM DATA=CLANO2WY;
47          CLASS TIME TRAN;
48          MODEL VEG3=TIME TRAN TIME*TRAN;
49          LSMEANS TIME TRAN TIME*TRAN;

NOTE: THE PROCEDURE GLM USED 0.28 SECONDS AND 318K AND PRINTED PAGES 10 TO 12.
NOTE: SAS USED 448K MEMORY.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PO BOX 8000
      CARY, N.C.  27511-8000
```

C.8 Photo Records of Plots.

TRANSECT I: Traffic at Cave Entrance

BEFORE

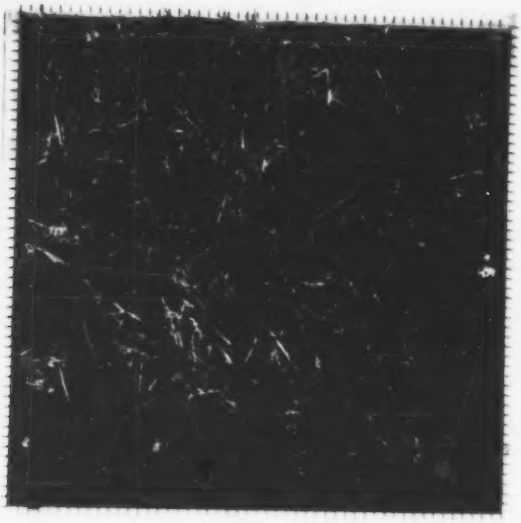


Plate C.8.1
Plot I-1 Date 28-6-1984

AFTER

Plot I-1 Date 6-9-1984

BEFORE

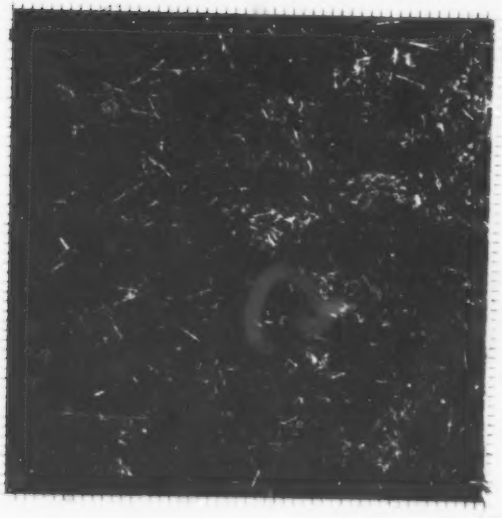
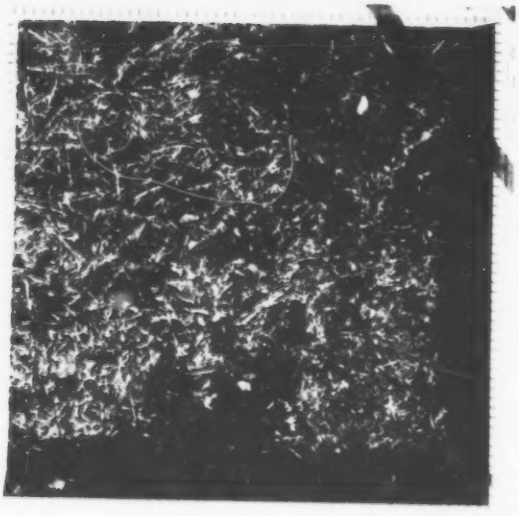


Plate C.8.2
Plot I-2 Date 28-6-1984

AFTER



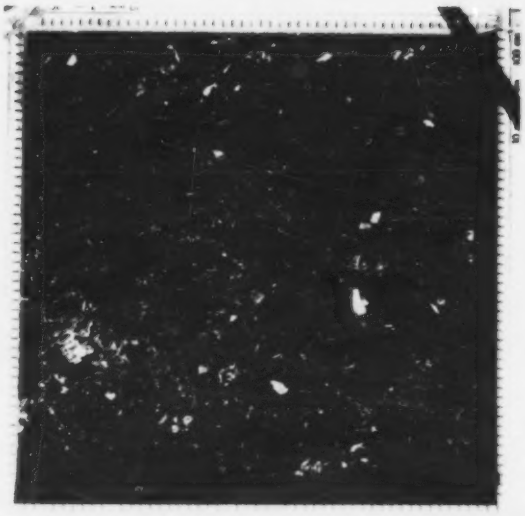
Plot I-2 Date 6-9-1984

TRANSECT I: Traffic at Cave Entrance

BEFORE

Plate C.8.3
Plot I-3 Date 28-6-1984

AFTER

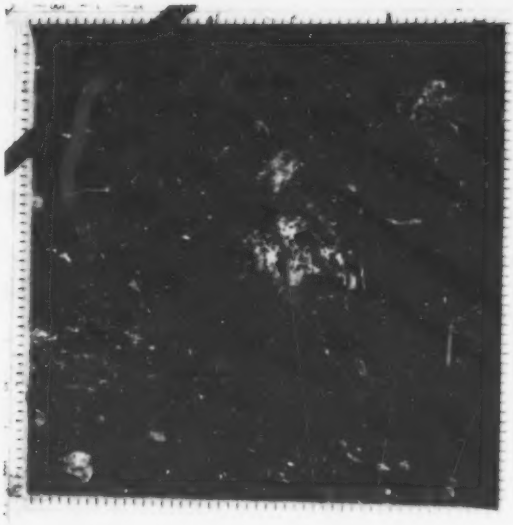


Plot I-3 Date 6-9-1984

BEFORE

Plate C.8.4
Plot I-4 Date 28-6-1984

AFTER



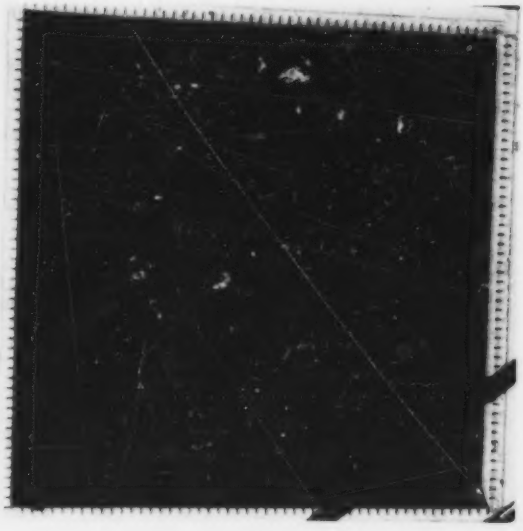
Plot I-4 Date 6-9-1984

TRANSECT I: Traffic at Cave Entrance

BEFORE

Plate C.8.5
Plot I-5 Date 28-6-1984

AFTER



Plot I-5 Date 6-9-1984

TRANSECT II: Traffic at Cave Entrance

BEFORE

Plate C.8.6
Plot II-1 Date 28-6-1984

AFTER

Plot II-1 Date 6-9-1984

TRANSECT II: Traffic at Cave Entrance

BEFORE

Plate C.8.7
Plot II-2 Date 28-6-1984

AFTER

Plot II-2 Date 6-9-1984

BEFORE

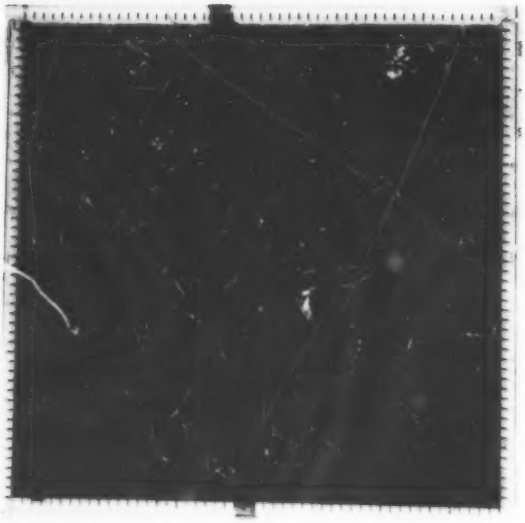
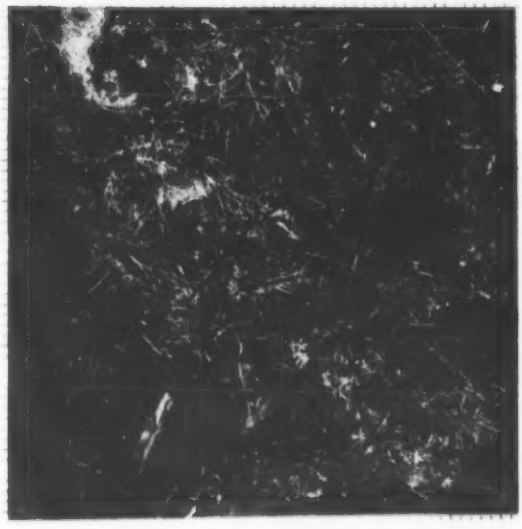


Plate C.8.8
Plot II-3 Date 28-6-1984

AFTER



Plot II-3 Date 6-9-1984

TRANSECT II: Traffic at Cave Entrance

BEFORE

Plate C.8.9
Plot II-4 Date 28-6-1984

AFTER

Plot II-4 Date 6-9-1984

BEFORE

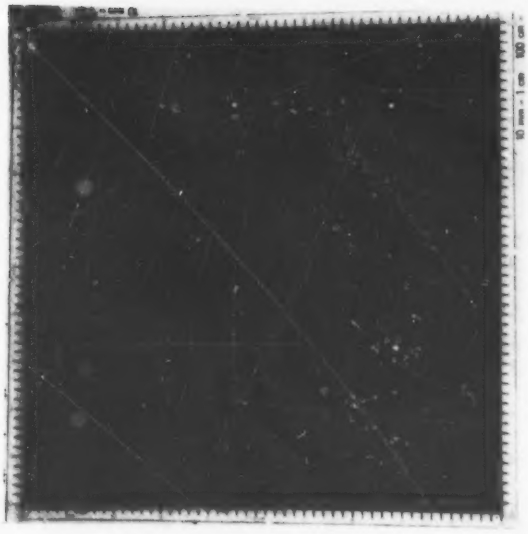
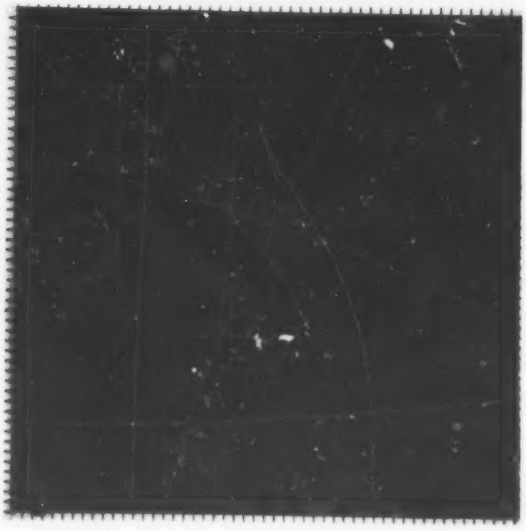


Plate C.8.10
Plot II-5 Date 28-6-1984

AFTER



Plot II-5 Date 6-9-1984

TRANSECT III: In Darkness Under Cave Platform

BEFORE

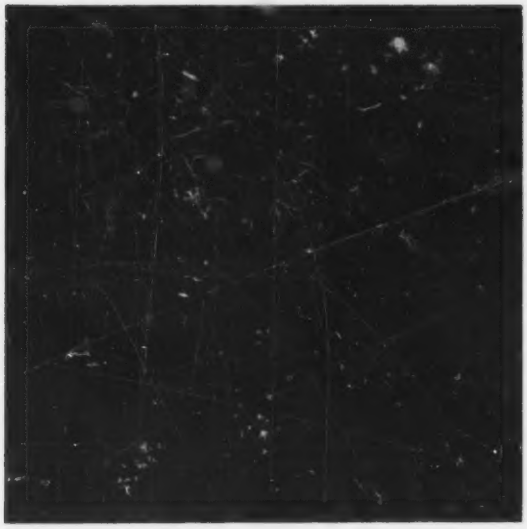


Plate C.8.11
Plot III-1 Date 1-6-1984

AFTER

Plot III-1 Date 6-9-1984

BEFORE

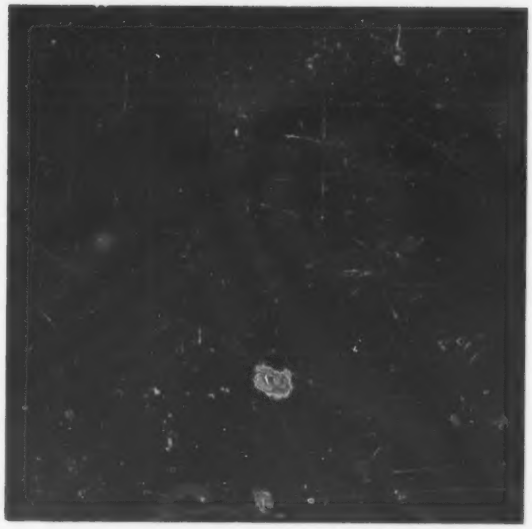


Plate C.8.12
Plot III-2 Date 1-6-1984

AFTER

Plot III-2 Date 6-9-1984

TRANSECT III: In Darkness Under Cave Platform

BEFORE

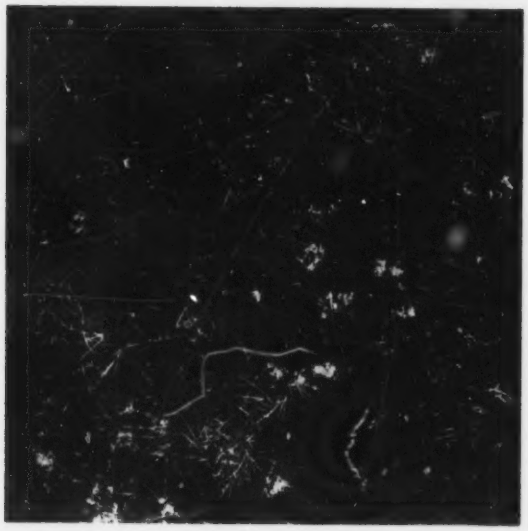


Plate C.8.13
Plot III-3 Date 1-6-1984

AFTER

Plot III-3 Date 6-9-1984

BEFORE

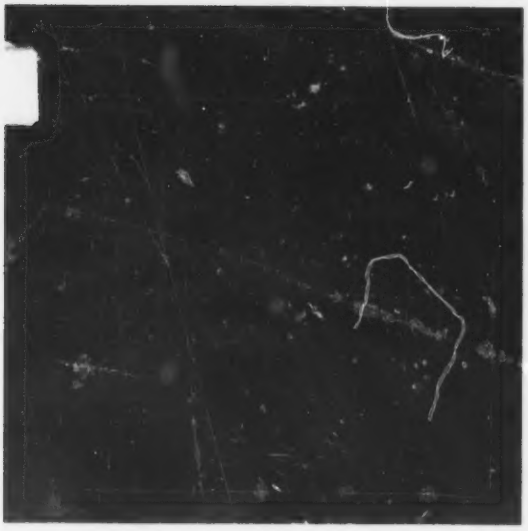


Plate C.8.14
Plot III-4 Date 1-6-1984

AFTER

Plot III-4 Date 6-9-1984

TRANSECT III: In Darkness Under Cave Platform

BEFORE

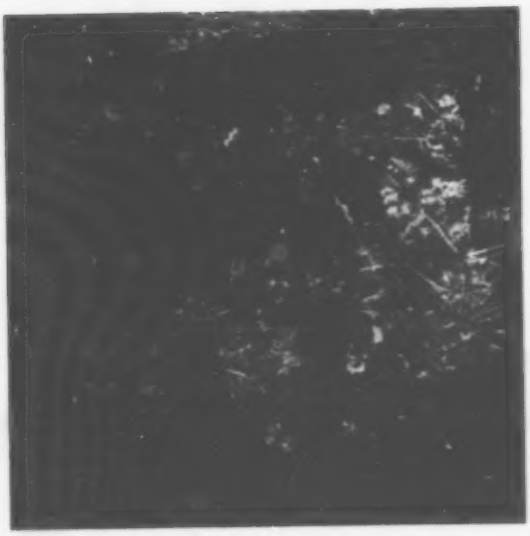


Plate C.8.15
Plot III-5 Date 1-6-1984

AFTER

Plot III-5 Date 6-9-1984

TRANSECT IV: No Impacts, Seasonal Growth (Control)

BEFORE

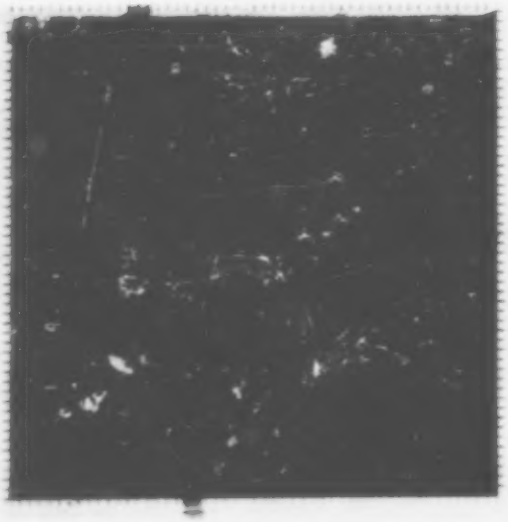
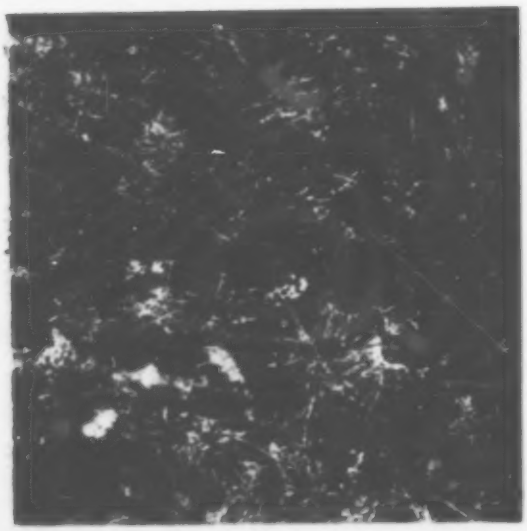


Plate C.8.16
Plot IV-1 Date 28-6-1984

AFTER



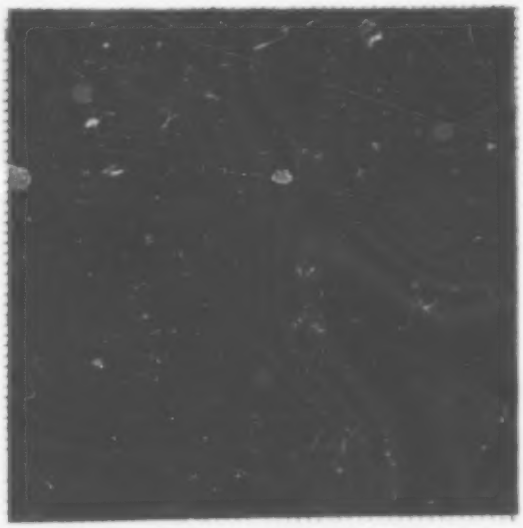
Plot IV-1 Date 6-9-1984

TRANSECT IV: No Impacts, Seasonal Growth (Control)

BEFORE

Plate C.8.17
Plot IV-2 Date 28-6-1984

AFTER



Plot IV-2 Date 6-9-1984

BEFORE

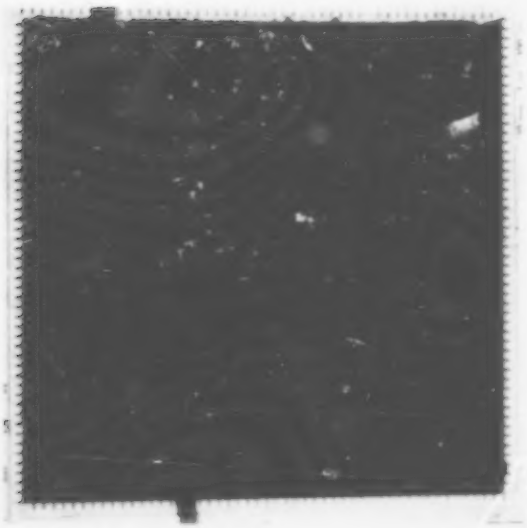
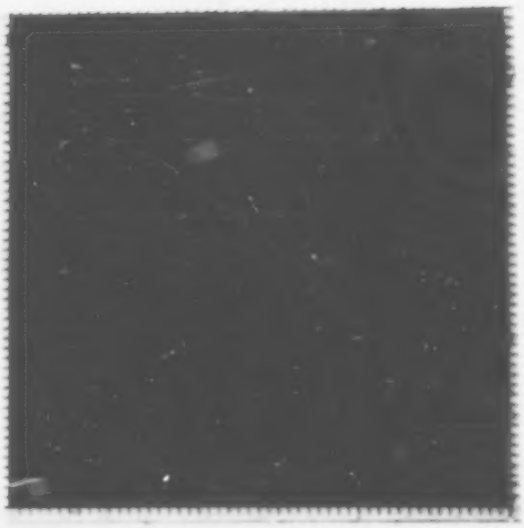


Plate C.8.18
Plot IV-3 Date 28-6-1984

AFTER



Plot IV-3 Date 6-9-1984

TRANSECT IV: No Impacts, Seasonal Growth (Control)

BEFORE

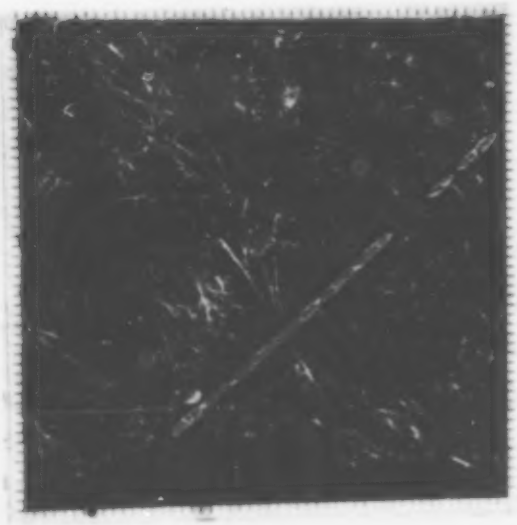


Plate C.8.19
Plot IV-4 Date 28-6-1984

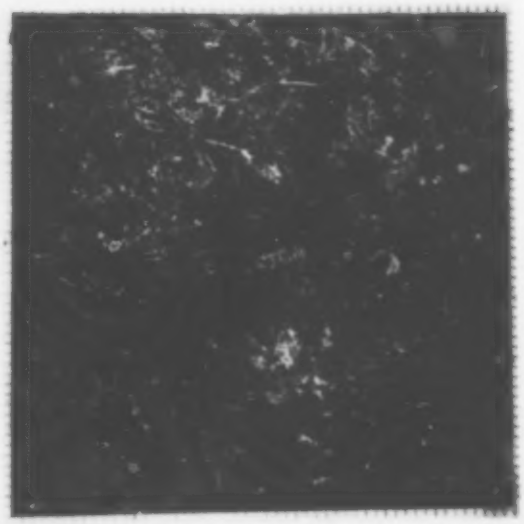
AFTER

Plot IV-4 Date 6-9-1984

BEFORE

Plate C.8.20
Plot IV-5 Date 28-6-1984

AFTER



Plot IV-5 Date 6-9-1984

TRANSECT V: Foot Traffic, 25 Walks/day for 34 Days by 180 lbs. Person on Smooth-Sole Shoes

BEFORE

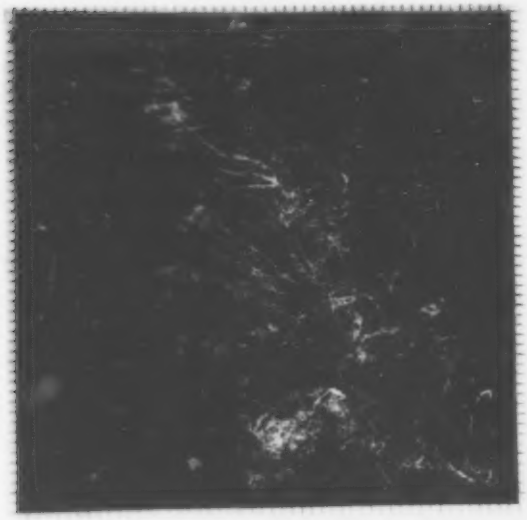


Plate C.8.21
Plot V-1 Date 28-6-1984

AFTER

Plot V-1 Date 6-9-1984

BEFORE

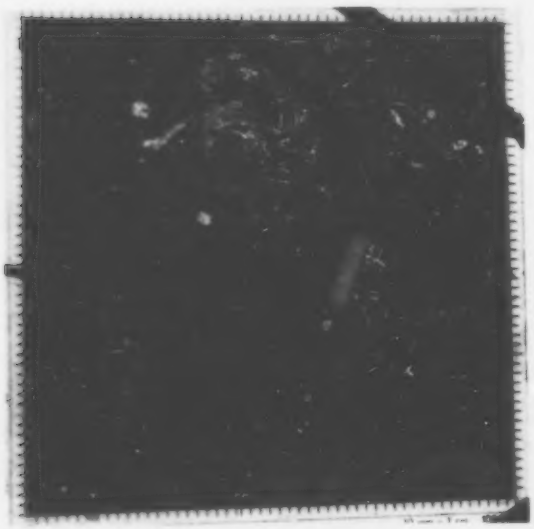


Plate C.8.22
Plot V-2 Date 28-6-1984

AFTER

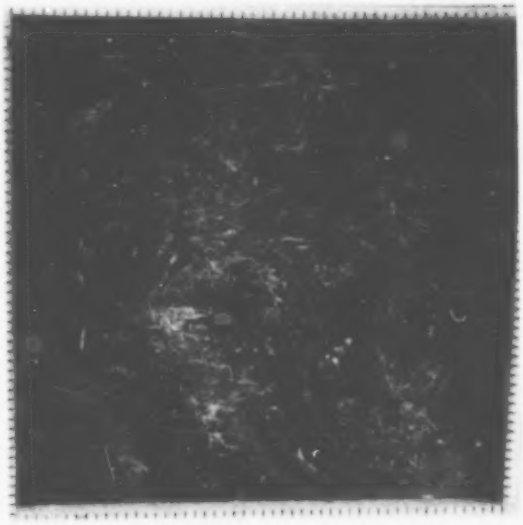
Plot V-2 Date 6-9-1984

TRANSECT V: Foot Traffic, 25 Walks/day for 34 Days by 180 lbs. Person on Smooth-Sole Shoes

BEFORE

Plate C.8.23
Plot V-3 Date 28-6-1984

AFTER



Plot V-3 Date 6-9-1984

BEFORE

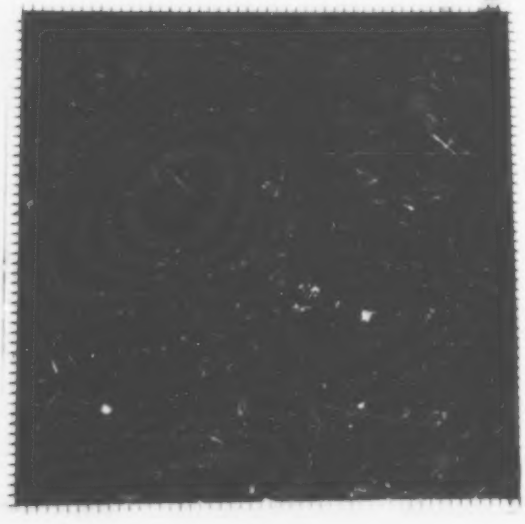
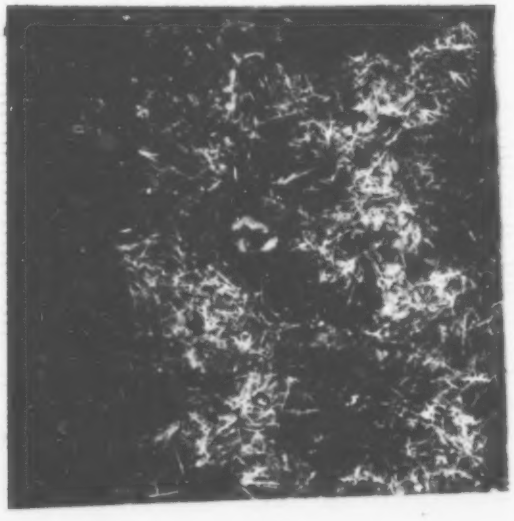


Plate C.8.24
Plot V-4 Date 28-6-1984

AFTER



Plot V-4 Date 6-9-1984

TRANSECT V: Foot Traffic, 25 Walks/day for 34 Days by 180 lbs. Person on Smooth-Sole Shoes

BEFORE

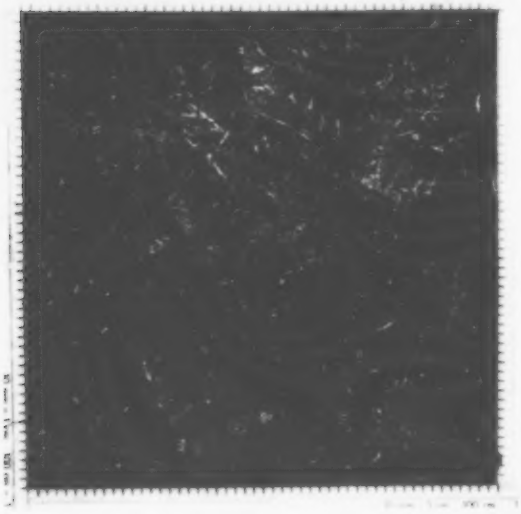
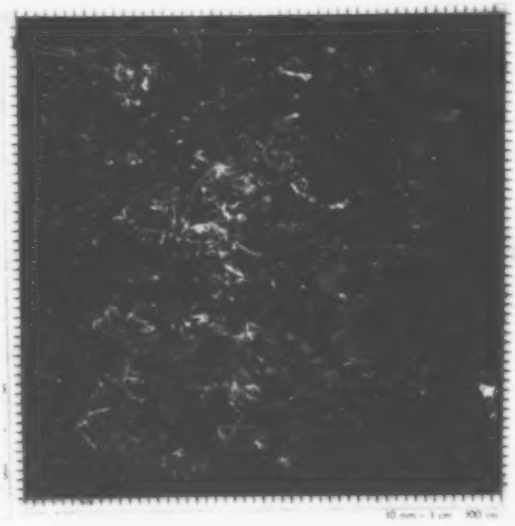


Plate C.8.25
Plot V-5 Date 28-6-1984

AFTER



Plot V-5 Date 6-9-1984

TRANSECT VI: Foot Traffic, 5 Walks/day for 32 Days by 180 lbs. Person on Smooth-Sole Shoes

BEFORE

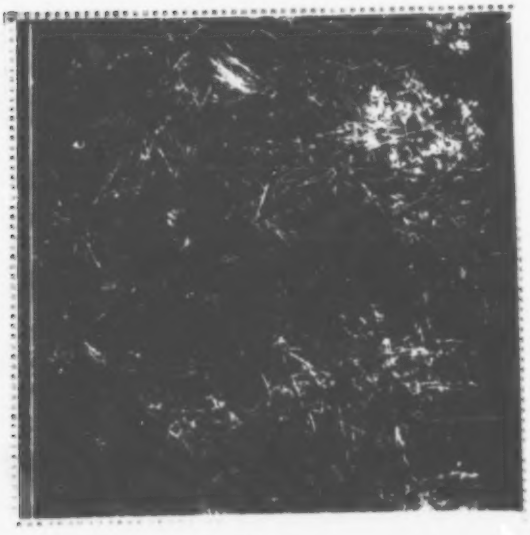
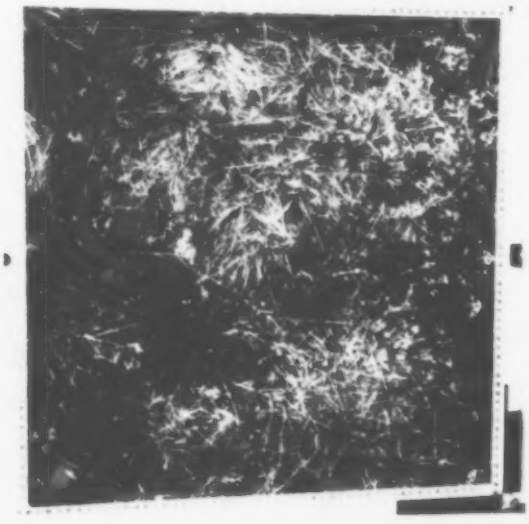


Plate C.8.26
Plot VI-1 Date 28-6-1984

AFTER



Plot VI-1 Date 6-9-1984

TRANSECT VI: Foot Traffic, 5 Walks/day for 32 Days by 180 lbs. Person on Smooth-Sole Shoes

BEFORE

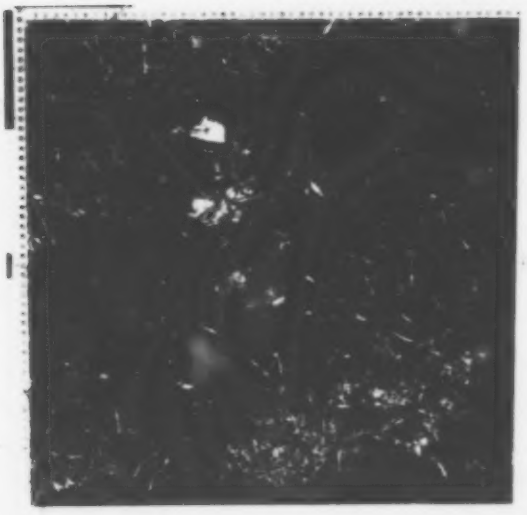
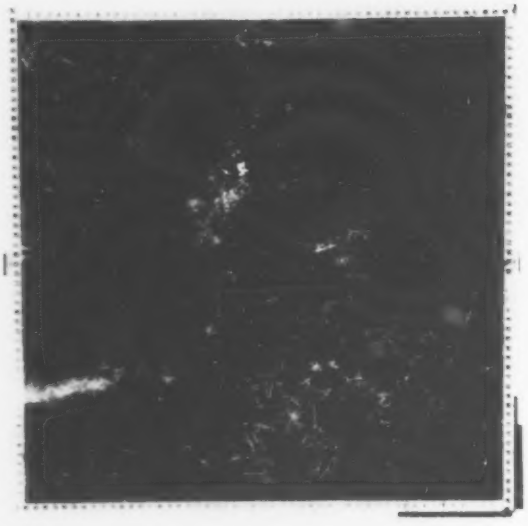


Plate C.8.27
Plot VI-2 Date 28-6-1984

AFTER



Plot VI-2 Date 6-9-1984

BEFORE

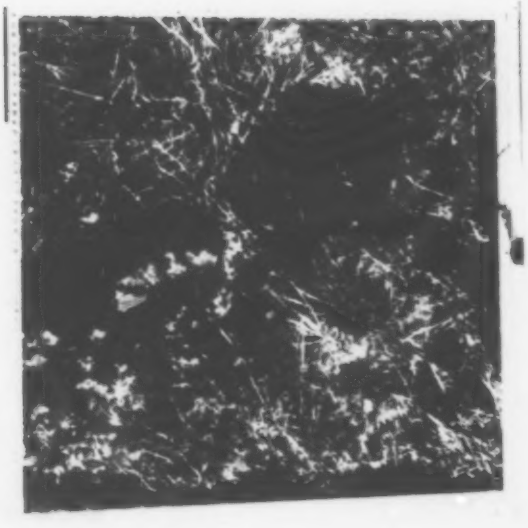
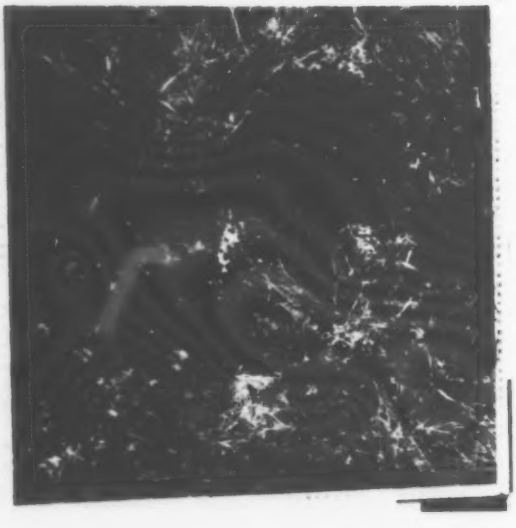


Plate C.8.28
Plot VI-3 Date 28-6-1984

AFTER



Plot VI-3 Date 6-9-1984

TRANSECT VI: Foot Traffic, 5 Walks/day for 32 Days by 180 lbs. Person on Smooth-Sole Shoes

BEFORE

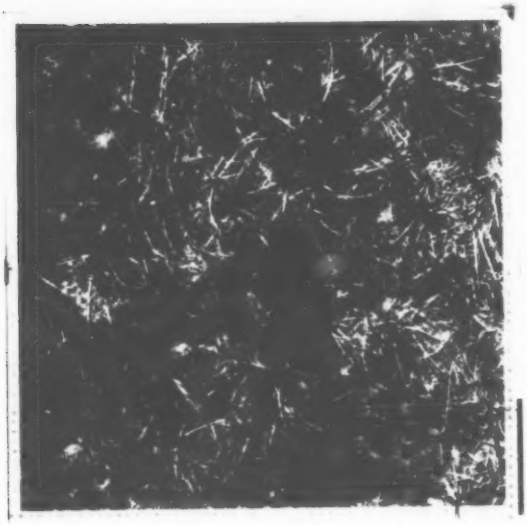
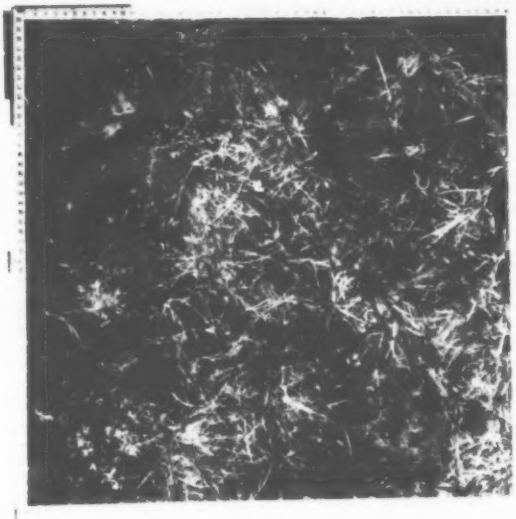


Plate C.8.29
Plot VI-4 Date 28-6-1984

AFTER



Plot VI-4 Date 6-9-1984

BEFORE

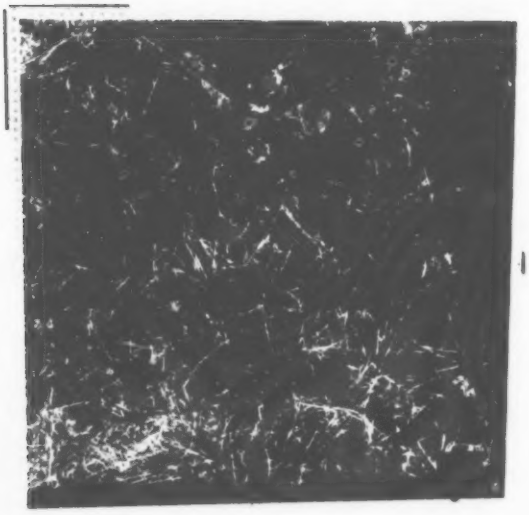
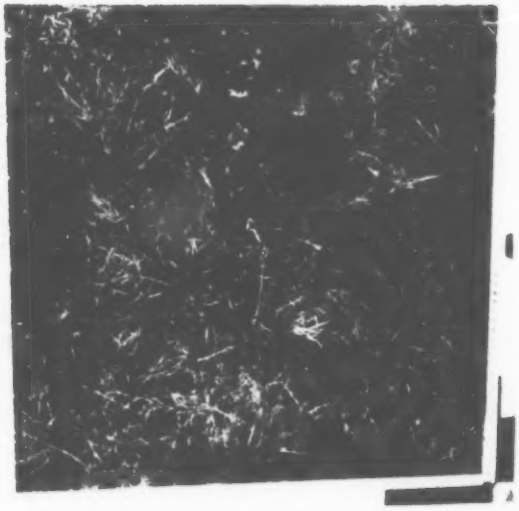


Plate C.8.30
Plot VI-5 Date 28-6-1984

AFTER



Plot VI-5 Date 6-9-1984

TRANSECT S(T): Traffic near Stageing Platform

BEFORE

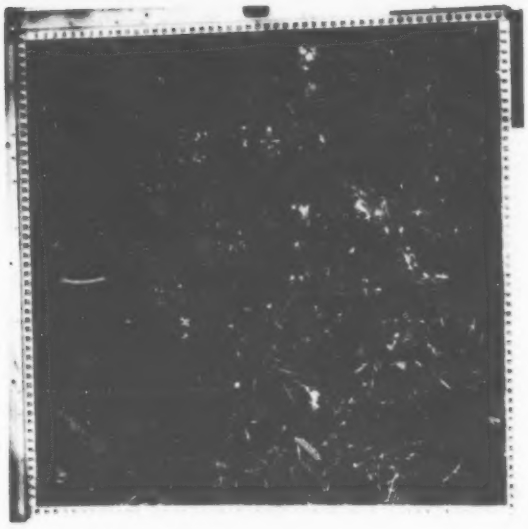
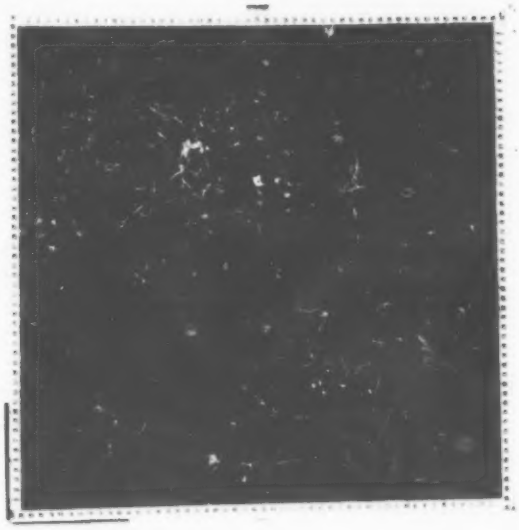


Plate C.8.31
Plot S(T)-1 Date 28-6-1984

AFTER



Plot S(T)-1 Date 6-9-1984

BEFORE

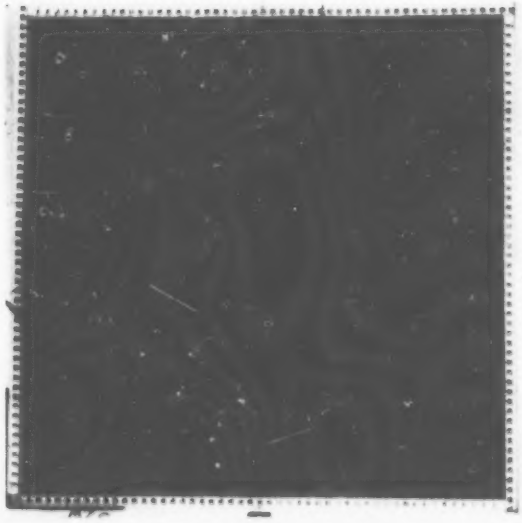
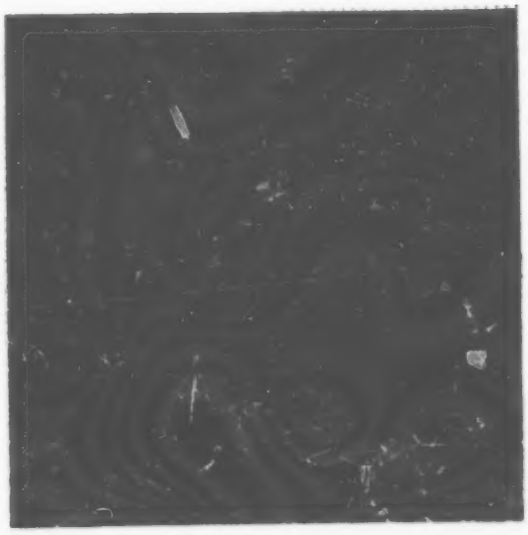


Plate C.8.32
Plot S(T)-2 Date 28-6-1984

AFTER



Plot S(T)-2 Date 6-9-1984

TRANSECT R: Under Walking Ramp, 9cm wide Boards, spaced 2cm apart, continous Stringer. Prior to and following freezing weather.

BEFORE

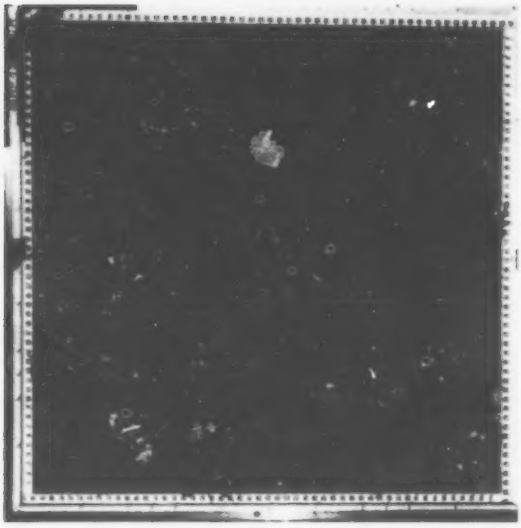
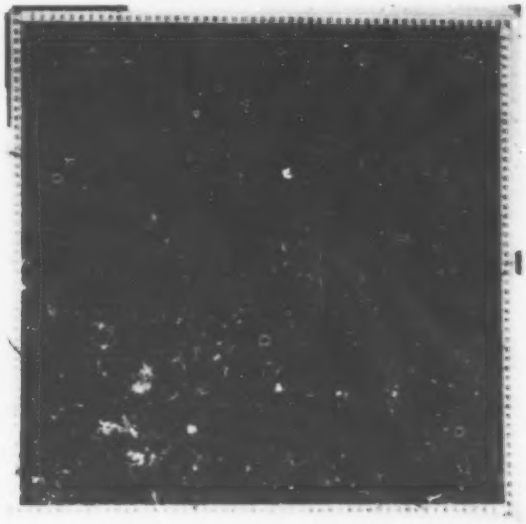


Plate C.8.33
Plot R-4C Date 28-6-1984

AFTER



Plot R-4C Date 6-9-1984

BEFORE

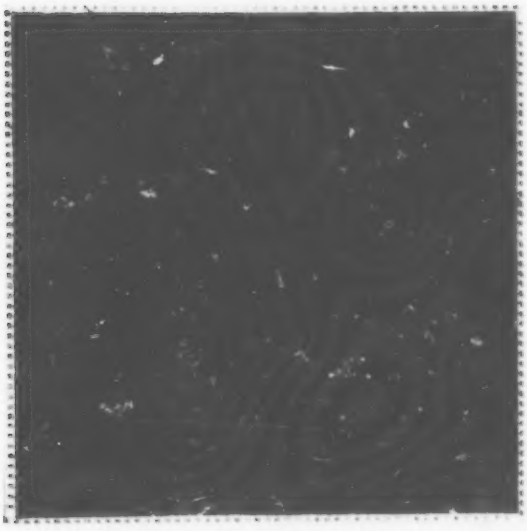
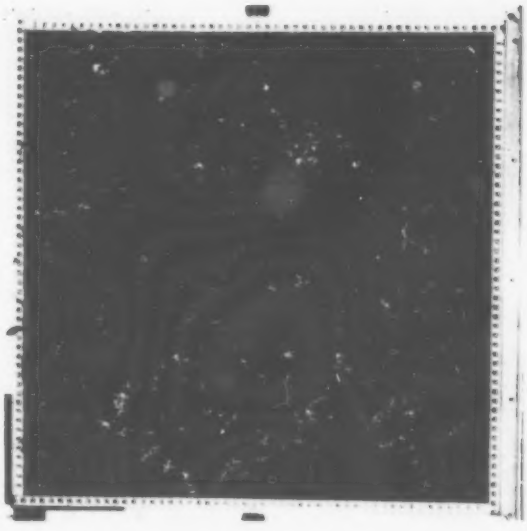


Plate C.8.34
Plot R-2C Date 28-6-1984

INTERIM



Plot R-2C Date 15-8-1984

TRANSECT R: Under Walking Ramp, 9cm wide Boards, spaced 2cm apart, continous Stringer. Prior to and following freezing weather.

BEFORE

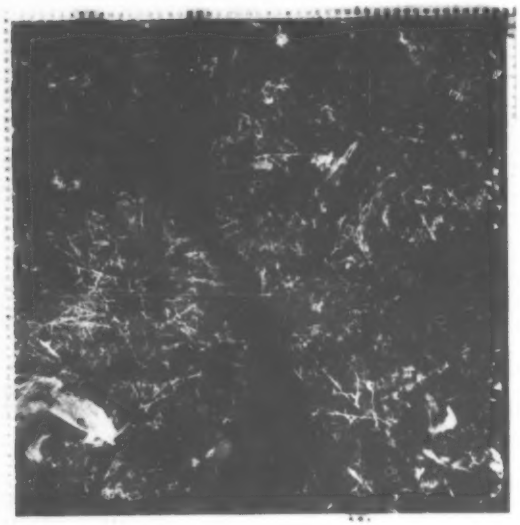
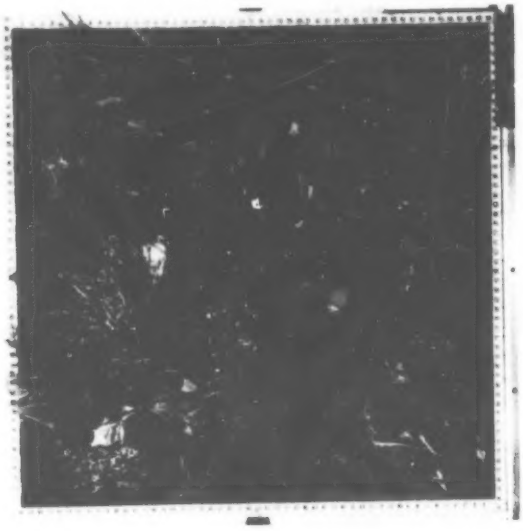


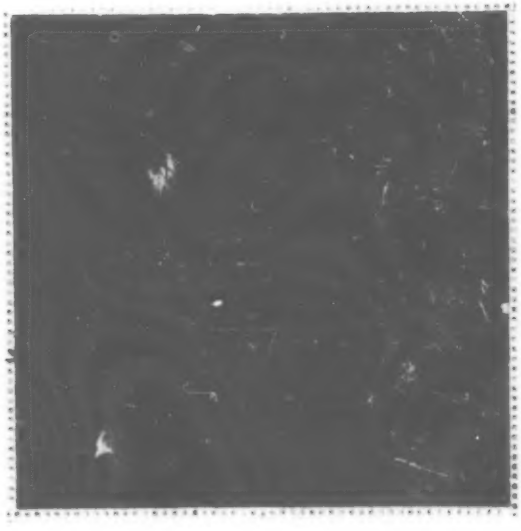
Plate C.8.35
Plot R-1 Date 28-6-1984

INTERIM



Plot R-1 Date 15-8-1984

AFTER



Plot R-1 Date 6-9-1984

TRANSECT R: Under Walking Ramp, 9cm wide Boards, spaced 2cm apart, continous Stringer. Prior to and following freezing weather.

INTERIM

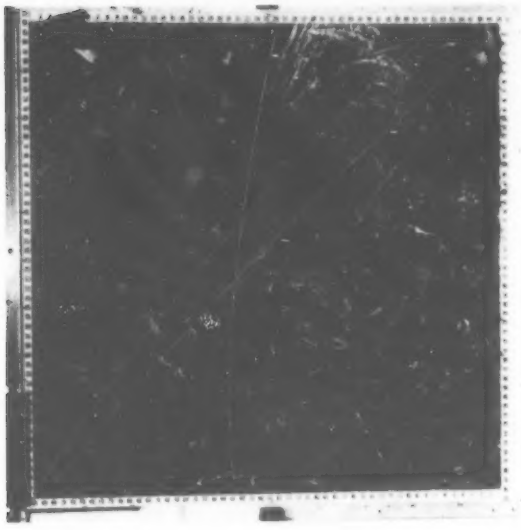
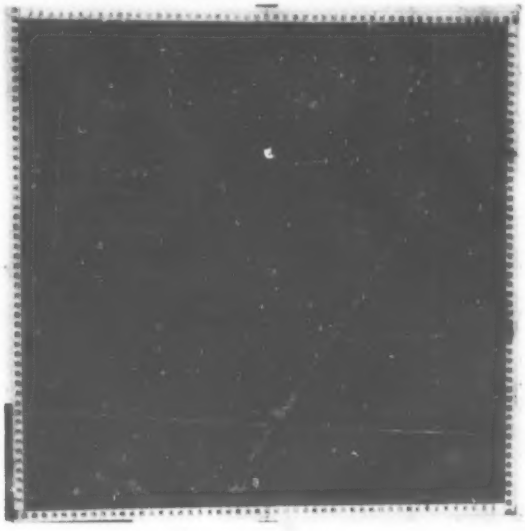


Plate C.8.36
Plot R-2 Date 15-8-1984

AFTER



Plot R-2 Date 6-9-1984

PAIRED PLOTS SPF: In Darkness Under Stageing Platform; Without and with screening; prior to and following freezing weather

INTERIM

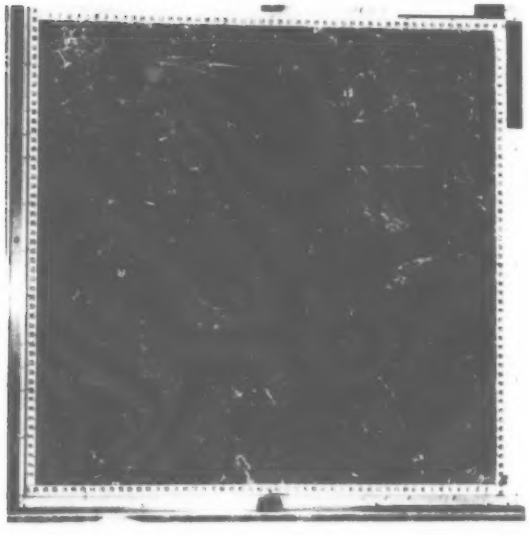
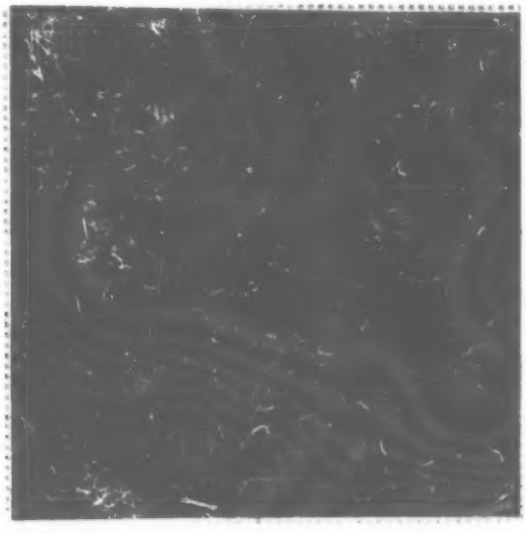


Plate C.8.37
Plot SPF-1 Date 15-8-1984

AFTER



Plot SPF-1 Date 6-9-1984

PAIRED PLOTS SPF: In Darkness Under Stageing Platform; Without and with screening; prior to and following freezing weather

INTERIM

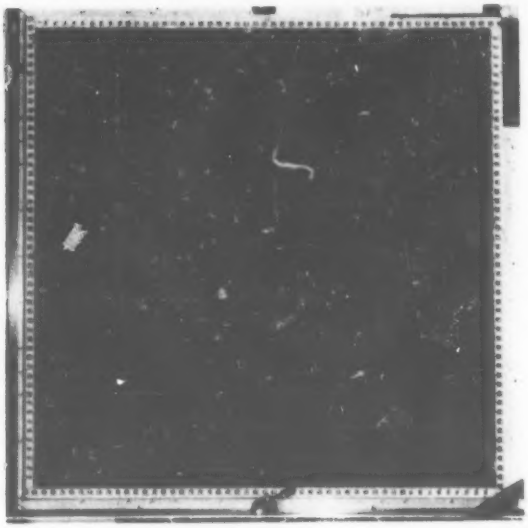


Plate C.8.38
Plot SPF-2 Date 15-8-1984

AFTER

Plot SPF-2 Date 6-9-1985

PAIRED PLOTS PF: In Darkness under Cave Platform with and without screened release; prior to and following freezing weather

INTERIM

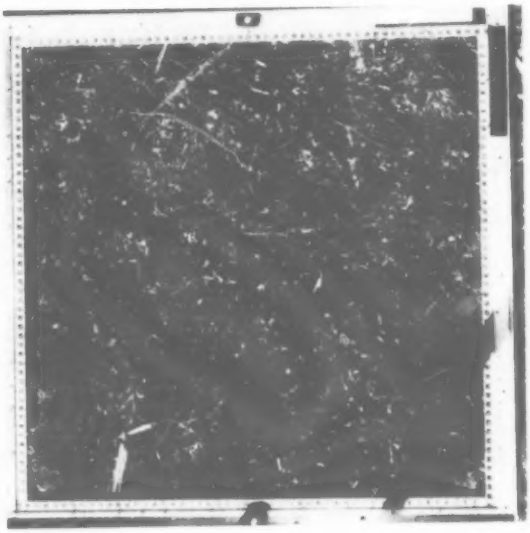
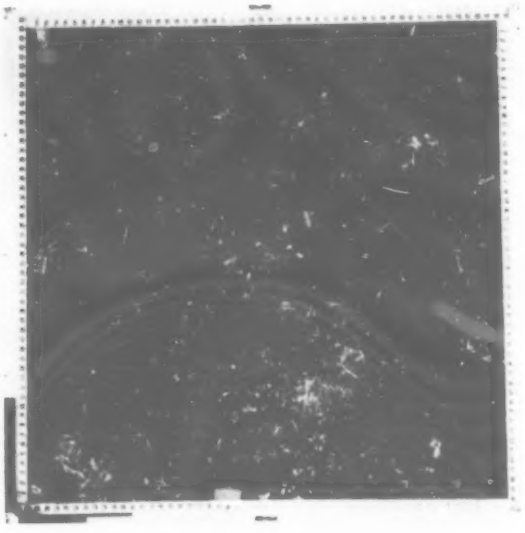


Plate C.8.39
Plot PF-1 Date 15-8-1984

AFTER



Plot PF-1 Date 6-9-1984

PAIRED PLOTS PF: In Darkness under Cave Platform with and without screened release; prior to and following freezing weather

INTERIM

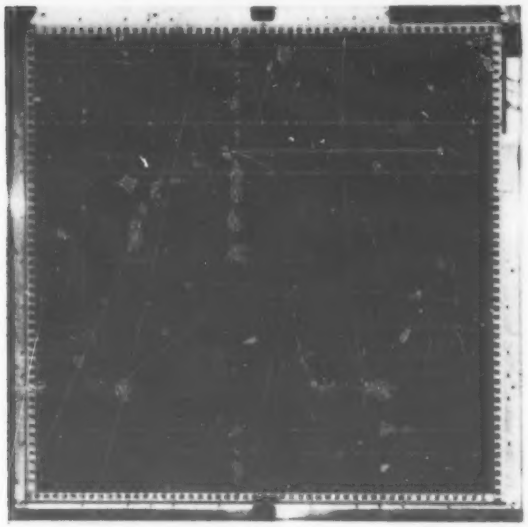
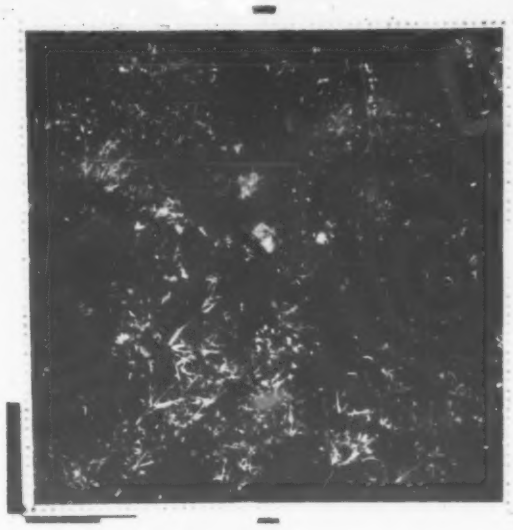


Plate C.8.40
Plot PF-2 Date 15-8-1984

AFTER



Plot PF-2 Date 6-9-1984